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WHY MILLIONS ON MATHS RETURNED LITTLE

ROSE PATTERSON

FOREWORD BY JEFF GREENSLADE

THE NEW ZEALAND INITIATIVE

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2015

The New Zealand Initiative is an independent public policy think tank supported by chief executives of major New Zealand businesses. We believe in evidence-based policy and are committed to developing policies that work for all New Zealanders.

Our mission is to help build a better, stronger New Zealand. We are taking the initiative to promote a prosperous, free and fair society with a competitive, open and dynamic economy. We develop and contribute bold ideas that will have a profound, positive, long-term impact.

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ABOUT THE AUTHOR

ROSE PATTERSON

Rose is a Research Fellow at The New Zealand Initiative working on education policy. She published three reports on teacher quality in 2013–14 with co-author John Morris, which included a research trip to Singapore, Finland, the United Kingdom, Germany and Canada, and published a report on school collaboration: *No School is an Island* in 2014. Rose has lived and worked in Japan, and worked as a Researcher for the Health Sponsorship Council for four years. She has a Master's degree in Psychology and a Bachelor of Commerce with a major in Marketing from the University of Otago. Rose writes opinion editorials on education regularly and has made radio and television appearances on educational issues.

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This report does not necessarily represent the views of any of those acknowledged here, and is the sole responsibility of the author.

FOREWORD

I have a confession to make. I was one of those kids at school who thought that maths was boring.

And I wasn't the only one – many of my friends thought the same. But we didn't have much choice. No matter how smart we thought we were, we were all expected to rote-learn and memorise. It was the same with spelling and grammar.

There was none of the more imaginative problem-solving and 'mental maths' that are taught in primary schools today. It was only much later, once a solid base of memorised facts was in place, that we were let loose on problem-solving.

Did we miss out on something because of that?

It's true the tedium of rote-learning meant that the prospect of a maths class didn't exactly make me spring out of bed in the morning.

But all of that rote-learning paid off. Even though I didn't realise it at the time, it gave us the capacity to memorise a great many facts and figures, without the help of Google or Wikipedia.

That solid foundation in the basics has served me well ever since. In fact, when I started working for a bank in my mid-20s, I found that I was drawing on maths principles I had memorised many years earlier.

Was that a better way to learn maths than what happens in New Zealand primary schools today, where rote-learning is rare and mental problem-solving is taught from an early age instead?

I don't know, but it is certainly a question worth exploring, particularly when you consider how New Zealand's international performance in school maths has declined over the past couple of decades.

With this report, the New Zealand Initiative is raising a timely discussion on this important subject. It argues that the move away from rote-learning in our primary schools over the past 15 years has meant that schoolkids no longer get the solid grounding in the basics of maths that they need.

So why does this matter? In a world where our children have phones with more computational power and access to information than they will ever need, what is the point of learning maths at all?

The answer is that maths teaches numeracy, and numeracy is more than just adding up numbers – it's an ability to see patterns and to think through problems logically, which is an essential life-skill.

Technology doesn't change that – if anything a more complex, interconnected and data-driven world makes basic numeracy even more important, because there are more demands on us for rapid calculation and decision-making.

A solid grasp of maths is necessary if our children are to grow up with the confidence and skills they need to take full advantage of the opportunities that come their way.

Finding the right balance in our schools to inspire and engage children in maths from an early age is critical for their success, and for New Zealand's.

Jeff Greenslade

CHIEF EXECUTIVE, HEARTLAND BANK

EXECUTIVE SUMMARY

Fifteen years ago, a wave rippled through New Zealand: The Ministry of Education introduced a new way of teaching maths in primary schools. The Numeracy Development Project (Numeracy Project) a centrally devised professional development (PD) programme for primary school maths teachers, was rolled out in 2001. The Numeracy Project changed the way maths is taught in New Zealand primary schools, putting more emphasis on teaching children multiple mental strategies for solving problems. It followed a series of smaller localised PD programmes in the mid- to late-1990s that showed signs of success. The Numeracy Project was intensive, with around 20 hours of PD for each primary school teacher in its first two years, and expensive, at a central cost of $70 million.

Maths performance has been in decline over the last 10 years, with losses in the basics

- Maths performance showed signs of improvement in the mid- to late-1990s, but has been in decline since then, although not back to early 1990s levels. There have been losses in the basics such as simple addition and multiplication, and children are no longer using vertical written methods for solving maths problems.
- It is a myth that children in the East Asian countries (that top the charts in maths) are just rote learning for the tests. Though they score highly on knowledge of basic facts, they are also better than New Zealand students at applying their knowledge to solve novel problems.

The Numeracy Project has put too much emphasis on multiple strategies, and not enough on the basics

- In tandem, curriculum changes over time show a move towards more 'relational' learning (discerning the connections between numbers and situations by mentally working out answers to maths problems, often using multiple strategies) over 'instrumental' learning (basic maths rules and processes using the traditional written form).
- Although the Ministry of Education maintains that both knowledge and strategies are important, children in New Zealand are spending more time explaining their answers in class and less time memorising facts, rules and procedures, compared to children in other countries, including the top performers.
- Relational learning is important, but so is gaining fluency in the basics and written methods, which frees up childrens' working memory to develop the deeper conceptual mathematical understanding the Numeracy Project intended.

Many primary school teachers may not be maths proficient to teach the new methods

- A 2010 study found that a third of new primary school teachers could not add two fractions (7/18 + 1/9). Yet today's emphasis on developing children's deeper conceptual understanding in maths may rely even more on teacher maths abilities.
- Both teacher maths proficiency and maths *teaching* proficiency (knowledge of how to represent mathematical concepts in ways children can understand) are predictive of student achievement in maths. Yet there are no objective assessments of whether graduating teachers have the required level of proficiency.
- Teacher salaries relative to other professional occupations such as law, accounting, engineering and science have stayed stable over the past 15 years. This makes the explanation that declines in maths are due to declines in teacher maths abilities unlikely.

The cost of the Numeracy Project has not been worth the benefit

The Numeracy Project has returned little benefit at substantial cost. This report outlines the problems with imposing a centrally planned, nationwide approach to teaching maths on top of a self-managing education system. It asks who is accountable for results. Parents have been asking questions about the new methods of teaching maths, and schools too have begun to question the methods.

Recommendations for consideration

The Numeracy Project shows that centrally devised approaches to changing instruction are not appropriate, nor do they necessarily return the intended benefit. As such, The New Zealand Initiative proposes that individual schools should weigh up whether they have the right balance of instrumental and relational learning for maths, and make adjustments if necessary. This report also makes the following recommendations for consideration:

- The Investing in Educational Success (IES) policy presents an opportunity for teachers strong in maths to share their expertise with other teachers. Communities of Schools[1] signing up for IES should consider how they can best share maths teaching knowledge.
- Schools in New Zealand adapt the national curriculum to each local context. The Ministry of Education should consider ways that the maths curriculums of successful schools can be shared with other schools serving similar student profiles.
- A certificate of maths teaching proficiency should be developed, based on a test of both maths ability and maths *teaching* ability (such tests, which validly predict maths teaching ability, have been devised overseas). This should not be mandated but be optional for teachers who want to gain their maths proficiency certification.

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1 Under the IES policy, groups of around ten schools are banding together to share expertise across their 'Community of Schools'. Funding for new teaching and leadership roles are available for each community.

INTRODUCTION

In the presentation *The Continued Economic Decline of the West* to the London School of Economics, Jon Moynihan, executive chairman of PA Consulting Group, explained that globalisation has and continues to open up large pools of unskilled labour markets.[2]

With the potential decline of low-skilled jobs here, if New Zealand parents want their children to succeed in the modern world, the very minimum they should expect from the education system is that their children acquire basic literacy and numeracy skills.

The egalitarian spirit that underlies the New Zealand culture would surely say that regardless of background, all children by the end of their primary school years should be able to read and write sufficiently to choose a range of paths at secondary school and beyond. Literacy and numeracy skills are not the end point. They are simply the beginning – a means to whatever ends lie ahead for the next generation. Many complex skills are required to succeed in today's world, and a solid grounding in maths is essential for accessing these skills.

Yet New Zealand children are struggling with even simple addition. This is not a new problem. Policymakers have been lamenting the state of maths education in primary schools for decades.

What is new is how maths is being taught in primary schools. This report documents a pendulum swing towards new methods of maths teaching, brought in by the Numeracy Development Project (Numeracy Project) in 2001. The traditional written vertical column methods of our parents' and grandparents' school days seem to have been relegated as relics of history. Children are now expected to know and use multiple strategies to solve maths problems, mostly in their heads. Parents across the country have been left in puzzlement as the new methods were rolled out from Wellington to lift maths performance. Yet, contrary to expectations, maths performance has been in decline since the Numeracy Project started.

This report makes the case that the overemphasis on strategies and underemphasis on facts and written procedures is holding children back from developing a deeper conceptual understanding of maths that the Numeracy Project set out to achieve. Educators should not abandon 'relational' learning (discerning connections between numbers and situations) but instead try to control the swing of the pendulum and return some of the focus to 'instrumental' learning (basic facts, rules and processes). If we had to think each time about how to move from first to second gear when driving, we could not concentrate on the road ahead. Similarly, children need to know their basic maths facts automatically to free up working memory for more complex maths. Policymakers and academics spoken to at the highest level for this report have reiterated that the Numeracy Project was never meant to take the emphasis off the basics, yet there have been some confusing messages from the Ministry of Education on where the emphasis should be.

Schools know that the Numeracy Project is flawed. Benjamin Riley, a Fulbright scholar who investigated education policymaking in New Zealand in 2014, found a high level of concern about the Numeracy Project in the schools he visited.

> Many principals and teachers expressed strong views around New Zealand's Numeracy Project in particular. At one urban decile 10 school, for example, the lead teacher responsible for mathematics suspected that the Numeracy Project had "swung the pendulum too far" in teaching strategies to solve maths problems rather than developing mathematical content knowledge and fluency in algorithms.[3]

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2 Jon Moynihan, "The Continued Economic Decline of the West – (and what, if anything, can we do to stop it?)," YouTube video (PA Consulting Group, 14 May 2012).

3 Benjamin Riley, "Science, Data and Decisions in New Zealand's Education System" (Wellington: Fulbright New Zealand, August 2014), pp. 36–37.

Riley quotes a secondary school maths teacher with a Master's degree in maths:

> They can say what they want, but repetition is key [to learning basic maths facts]. We almost need to start from scratch with students, and undo bad practices... Their basic number skills are bad. They come in and cannot divide at all. They do not see multiplication as multiple addition. Kids [are being given] too many strategies, they can't decide which is better. In maths, there should be freedom... but there is also order.[4]

Riley's research also indicates an acknowledgement among educators that procedural proficiency and basic facts need improving. As such, many schools have begun rejecting the notion that written methods and rote learning are not important – and are likely turning things around. This report's recommendations acknowledge that each of New Zealand's 1,900 self-managing primary schools is at a different stage of maths education. It therefore avoids blanket policy recommendations – a centrally devised approach to fixing the maths problem would likely see the pendulum swing wildly back towards teaching children how to do algorithms with procedural fluency but without understanding. Instead, this report suggests ideas for improving maths instruction to debate and discuss.

This report addresses one piece of the puzzle, but there are likely other intersecting factors that explain why maths performance has been in decline over the last 10 years or so. For example, in New Zealand, primary school teachers tend to group children by ability within their classes. And, children within a class tend to work on different levels of the curriculum rather than progressing together.[5] New Zealand has also had a culture of low expectations in schools. The Ministry of Education released information in March 2015 attributing the decline in maths performance to a lack of emphasis on geometry and algebra in the curriculum.[6]

It should also be acknowledged that there have been changes over recent years, not detailed in this report, that have likely shifted the landscape of maths education in primary schools. The 2007 National Curriculum put more emphasis on basic facts, and the National Standards introduced in 2009 emphasised teachers reporting to parents on students' progress in maths, reading and writing. Another more recent initiative showing positive results is the Accelerated Learning in Mathematics (ALiM) programme. Many schools are now using technology as a learning tool, and this is likely also having significant implications for the way children learn maths.

This report covers the Numeracy Project story in five chapters:

Chapter 1, "Kiwi Kids Cannot Add", reviews maths achievement data, looking at both time trends over the past 15 years, and international comparisons. It outlines New Zealand's performance in maths and compared to other countries, and points to evidence of losses in maths basics.

Chapter 2, "Too Many Strategies, Not Enough Facts", tracks the history of the Numeracy Project.

Chapter 3, "A Constant in the Equation: Teachers Struggle with Maths", points to evidence that primary school teachers, in general, may not have the required levels of maths competency themselves to teach the new methods.

Chapter 4, "Central Plans", discusses the systemic and cost issues of rolling out a centrally devised programme in a self-managing school system.

Chapter 5, "Solutions", presents policy ideas for debate and discussion: schools successful in maths education sharing their curriculums and lesson plans with schools serving a similar profile of students, and introducing a voluntary primary school teacher certificate (and test) of maths teaching proficiency.

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4 Ibid., p. 37.

5 Ina V.S. Mullis, et al. (eds), "TIMSS 2011 Encyclopedia: Education Policy and Curriculum in Mathematics and Science," Volume 2: L–Z and Benchmarking Participants (Boston: TIMSS & PIRLS International Study Center Lynch School of Education, Boston College, 2012), p. 636.

6 Nicholas Jones, "Students aren't being taught maths correctly, creating a 'huge' learning gap," *The New Zealand Herald* (5 March 2015).

CHAPTER ONE
KIWI KIDS CANNOT ADD

In 2011, New Zealand's performance on the Trends in International Mathematics and Science Study (TIMSS) of primary school children showed that almost half of New Zealand's Year 5 students could not add 218 and 191.[7] In 2012, the Programme for International Student Assessment (PISA) showed that 23% of New Zealand's 15-year-olds (16% in 2009)[8] were not reaching the level of mathematical aptitude the Organisation for Economic Co-operation and Development (OECD) considers necessary for competently participating in the real world. Both surveys confirmed what many New Zealand parents and teachers already knew: Kiwi children are struggling with maths.

Could it simply be, as popular opinion seems to suggest, that New Zealand scores low on international rankings compared to top performing jurisdictions like Singapore, South Korea, Japan and Shanghai because New Zealand children do not score well on the stuff that can be committed to memory or worked out with an efficient algorithm?

This chapter looks at New Zealand students' maths performance over time and in an international context. It presents data on different aspects of maths learning. It is not enough, for example, to know how to add 218 and 191 quickly. It is knowing, when presented with a novel problem, which operations to use to solve the problem, and then how to carry out the operation fluently. Arguably, in this case, the quickest way (without using a calculator) is to work out the answer on paper using the vertical column method.

This chapter also disproves the popular misconception that New Zealand students' strengths are in solving maths problems; busts the myth that the East Asian countries top the international league tables in maths performance because their children have rote learned everything they need to know to do well on tests; and argues that it is the basics, plus knowing how and when to use the basics, that explains why children in these Asian countries are so good at maths.

7 Ina V.S. Mullis, Michael O. Martin, Pierre Foy and Alka Arora, "TIMSS 2011 International Results in Mathematics" (Boston: TIMSS & PIRLS International Study Center Lynch School of Education, Boston College, 2012), p. 96.

8 Steve May, Saila Cowles and Michelle Lamy, "PISA 2012: New Zealand Summary Report" (Wellington: Ministry of Education, December 2013).

BOX 1: MATHS: KNOWING WHAT, HOW AND WHEN

Studies such as PISA, TIMSS and NEMP (New Zealand's National Education Monitoring Project)[9] are sophisticated tools to understand children's abilities to use mathematical facts, concepts, procedures and reasoning in different strands of maths, such as number, geometry, statistics and algebra, and also to discern mathematical cognitive functioning.

TRENDS IN MATHEMATICS AND SCIENCE STUDY (TIMSS)

TIMSS measures the maths abilities of Year 5 and Year 9 students under three cognitive domains: *knowing*, *applying* and *reasoning*. Example questions from the International Association for the Evaluation of Educational Achievement (IEA) are shown to illustrate these three domains.

Knowing facts, procedures and concepts is necessary for further mathematical processing. According to the IEA:

> Without access to a knowledge base that enables easy recall of the language and basic facts and conventions of number, symbolic representation, and spatial relations, students would find purposeful mathematical thinking impossible.[10]

Q 1 EXAMPLE (KNOWING)

What does xy + 1 mean?

A. Add 1 to y, then multiply by x
B. Multiply x and y by 1
C. Add x to y, then add 1
D. Multiply x by y, then add 1

Q 1 (Year 9) is categorised under the cognitive domain of *knowing* because all the cognitive effort is in recalling knowledge, in this case: 1) that the two letters presented in algebraic form (x and y) like this indicate they are to be multiplied together; and 2) the rule that multiplication is to be done before addition.

Applying knowledge is the ability to apply "mathematical knowledge of facts, skills, and procedures or understanding of mathematical concepts to create representations".[11]

Q 2 EXAMPLE (APPLYING)

Duncan first travelled 4.8 km in a car and then he travelled 1.5 km in a bus. How far did he travel?

A. 6.3 km
B. 5.8 km
C. 5.13 km
D. 4.95 km

In Q 2 (Year 5), the first and predominant cognitive task is to work out which mathematical tool to use, that is, add the two distances – hence, TIMSS categorises it as a question that measures *applying*. However, answering the question correctly also requires *knowing* (fluency in recalling and carrying out the process of addition).

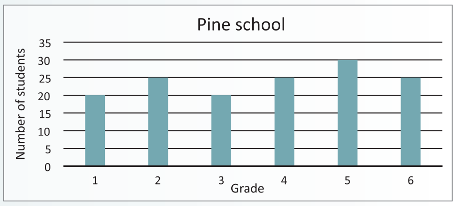
According to TIMSS, *reasoning* mathematically is:

> … the capacity for logical, systematic thinking. It includes intuitive and inductive reasoning based on patterns and regularities that can be used to arrive at solutions to non-routine problems… They make cognitive demands over and above those needed for the solution of routine problems, even when the knowledge and skills required for their solution have been learned.[12]

Q 3 EXAMPLE (REASONING)

The graph shows the number of students at each grade in the Pine School. There is room in each grade for 30 students. How many more students could be in the school?

A. 20
B. 25
C. 30
D. 35



9 The successor study to the NEMP is the National Monitoring Study of Student Achievement (NMSSA). Maths was assessed for the first time in 2014, and results are due to be released in 2015.

10 Ina V.S. Mullis, Michael O. Martin, Graham J. Ruddock, Christine Y. O'Sullivan and Corinna Preuschoff, "TIMSS 2011 Assessment Frameworks" (Boston: TIMSS & PIRLS International Study Center Lynch School of Education, Boston College, September 2009), p. 41.

11 Ibid, p. 43.

12 Ibid, p. 45.

Q 3 (Year 5) requires students to *reason* through the problem and add up the capacity available in each classroom. Again, without *knowing* how to quickly subtract or add, students will struggle with this problem. But students also have to connect the abstract to the real. Each bar is an abstraction of a classroom and a representation of the number of students in that classroom.

PROGRAMME FOR INTERNATIONAL STUDENT ASSESSMENT (PISA)

PISA splits the mathematical ability of 15-year-old students into three cognitive domains or processes: *formulating*, *employing* and *interpreting*. Examples from the OECD are shown for illustration.

Formulating situations is the ability to translate a mathematical problem "into a form that is amenable to mathematical treatment".[13]

Q 1 EXAMPLE (FORMULATING)

Mount Fuji is only open to the public for climbing from 1 July to 27 August. About 200,000 people climb Mount Fuji during that time. On average, about how many people climb Mount Fuji each day?

A. 340
B. 710
C. 3,400
D. 7,100
E. 7,400

In Q 1, most of the cognitive effort is in turning the information into a formula (number of people divided by number of days). Students also need to translate the time period (1 July to 27 August) into the number of days and then carry out the calculation. Key to solving this problem is understanding place value and using estimates. In this case, exact processes actually make solving the problem more difficult.

Q 2 EXAMPLE (EMPLOYING)

Toshi wore a pedometer to count his steps on the 9 km Gotemba trail. He walked 22,500 steps. Estimate his average step length in cm.

In Q 2, most of the cognitive effort is in converting kilometres into centimetres and arranging that information into a formula (distance = no. of steps x step length). Students need to *employ mathematical concepts, facts, procedures and reasoning* (know which mathematical tool to use and apply it "in a systematic and organized way to work towards a solution"[14]). The question also requires a knowledge of estimates (using place value).

Interpreting, applying and evaluating mathematical outcomes involve linking the calculated answer to the original problem.

Q3 EXAMPLE (INTERPRETING, APPLYING AND EVALUATING)

Chris wants a car that meets all of these conditions: The distance travelled is not higher than 120,000km; it was made in the year 2000 or later, the advertised price is not higher than 4,500 zeds. Which car meets all these conditions?

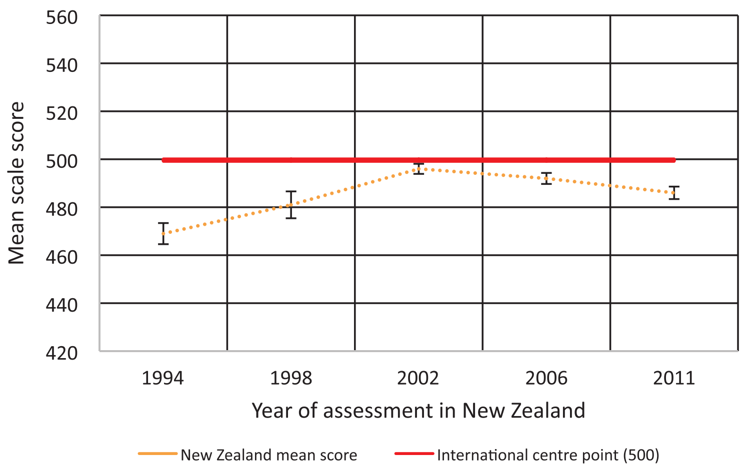
Model	Alpha	Bolte	Castel	Dezal
Year	2003	2000	2001	1999
Advertised price (zeds)	4 800	4 450	4 250	3 990
Distanced travelled kilometres)	105 000	115 000	128 000	109 000
Engine capacity (litres)	1.79	1.796	1.82	1.783

In Q 3, most of the cognitive effort is in using the information in the table to work out a 'real world' problem.

13 OECD, *PISA 2012 Results: What Students Know and Can Do*, Volume I: Student Performance in Mathematics, Reading and Science (Paris: PISA, OECD Publishing, 2014), p. 79.

14 Ibid., p. 83.

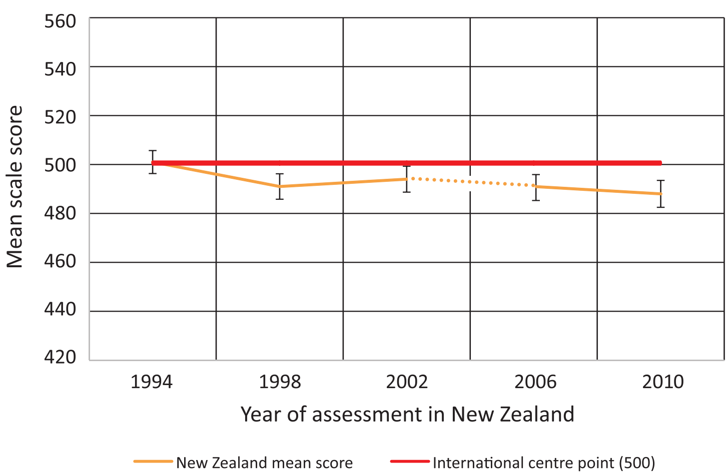
Figure 1. Mean mathematics performance of Year 5 students in TIMSS (1994 to 2011)



Source: Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 5 Students' Mathematics Achievement in 2010/11," New Zealand Results from the Trends in International Mathematics and Science Study (TIMSS) (Wellington: Ministry of Education, July 2013), p. 27.

Note: The values for the points are shown in Table 1.

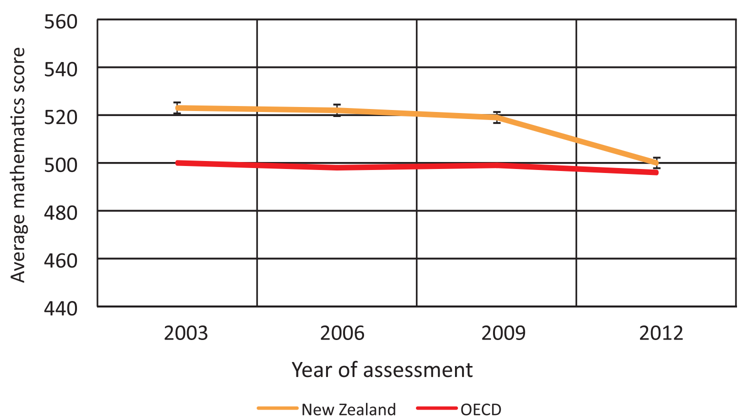
Figure 2. Mean mathematics performance of Year 9 students in TIMSS (1994 to 2010)



Source: Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 9 Students' Mathematics Achievement in 2010/11," New Zealand Results from the Trends in International Mathematics and Science Study (TIMSS) (Wellington: Ministry of Education, July 2013), p. 29.

Note: New Zealand did not conduct the TIMSS assessment in 2006 so the dotted line indicates the possible location of mean achievement in that cycle.

Figure 3. Mean mathematics performance of 15-year-olds in PISA (2003 to 2012)



Source: Steve May, Saila Cowles and Michelle Lamy, "PISA 2012 New Zealand Summary Report" (Wellington: Ministry of Education, December 2013), p. 13.

TIME TRENDS

TIMSS has been conducted five times with Year 5 students (1994, 1997, 2002, 2006 and 2010), and four times with Year 9 students (1994, 1997, 2002 and 2011) in maths and science. PISA has measured 15-year-olds' performance in maths (and reading and science) every three years since 2000. And New Zealand's NEMP ran in 1997, 2001, 2005 and 2009 to measure primary school curriculum subject performance, including maths.

Figures 1, 2 and 3 show improvements in New Zealand's primary school students in the 1990s, with peak performance and the narrowest range of scores in 2002 in PISA and TIMSS. Since then, however, performance has been in decline for primary and early secondary school students, although not to levels seen in 1994. For mid-secondary students, maths performance was fairly steady from 2000 until 2009, but in 2012 there was a large drop in performance and an increase in the proportion of students well below achieving.

Tables 1, 2 and 3 show the distribution of achievement, and changes in the proportions of students achieving at different levels, for TIMSS Year 5, TIMSS Year 9 and 15-year-olds in PISA, respectively.

Table 1. Distribution of mathematics achievement of New Zealand Year 5 students in TIMSS (1994 to 2011)

Year	Mean mathematics score	Range from 5th to 95th percentile	Inter-quartile range from 25th to 75th percentile
1994	469 (4.4)	316	125
1998	481 (5.6)	312	126
2002	496 (2.1)	273	114
2006	492 (2.3)	284	117
2011	486 (2.6)	274	113

Distribution of mathematics achievement

Source: Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 5 Students' Mathematics Achievement in 2010/11," New Zealand Results from the Trends in International Mathematics and Science Study (TIMSS) (Wellington: Ministry of Education, July 2013), p. 28.

Note: Standard errors are presented in parentheses.

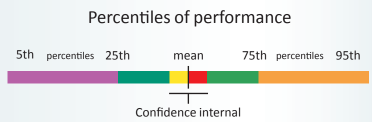
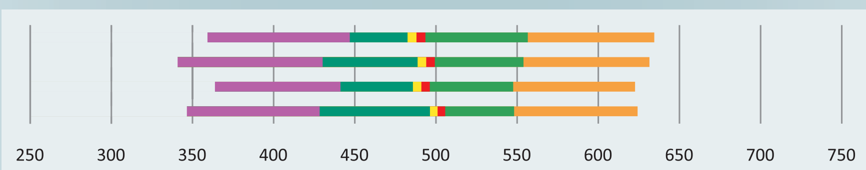


Table 2. Distribution of mathematics achievement of New Zealand Year 9 students in TIMSS (1994 to 2010)

Year	Mean mathematics score	Range from 5th to 95th percentile	Inter-quartile range from 25th to 75th percentile
1994	501 (4.7)	278	120
1998	491 (5.2)	259	106
2002	494 (5.3)	291	124
2010	488 (5.5)	275	110

Distribution of mathematics achievement



Source: Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 9 Students' Mathematics Achievement in 2010/11," New Zealand Results from the Trends in International Mathematics and Science Study (TIMSS) (Wellington: Ministry of Education, July 2013), p. 30.

Note: Standard errors are presented in parentheses.

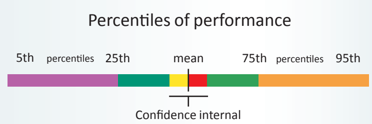


Table 3. Distribution of mathematics achievement of New Zealand 15-year-olds in PISA (2003 to 2012)

	Mean mathematics score	10th percentile	25th percentile	75th percentile	90th percentile	Range from 10th to 90th percentile	Interquartile from 25th to 75th percentile
2003	523 (2.3)	394 (3.9)	455 (2.9)	593 (2.2)	650 (3.2)	256	138
2006	522 (2.4)	401 (4.1)	458 (3.2)	587 (3.0)	643 (4.0)	242	129
2009	519 (2.3)	392 (4.4)	454 (2.8)	589 (3.1)	642 (3.9)	250	135
2012	500 (2.2)	371 (3.6)	428 (3.2)	570 (2.8)	632 (3.0)	261	142

Source: OECD, "PISA 2012 Results: What Students Know and Can Do," Student Performance in Mathematics, Readings and Science (Paris: PISA, OECD Publishing, 2014), pp. 308–309.

Note: Standard errors are presented in parentheses.

TIME TRENDS FOR CONTENT AND COGNITIVE DOMAINS

TIMSS comparisons in the different strands of maths and the cognitive domains are limited to 2006 and 2011. While there were no changes in *number* during this period for Year 5 students, there were significant decreases in *geometric shapes and measures* and *data display*. For Year 9 students, the only change in the content domains was that algebra weakened between 2006 and 2010.[15]

For Year 5 students in cognitive domains, since 2006, there have been no changes in *knowing* and *applying* but significant decreases in *reasoning*.[16] Year 9 students showed no changes over the same time period (2006 to 2010) in the cognitive domains.

New Zealand's NEMP studies reveal interesting findings when comparing performance on some of the same questions in different years. Although Year 4 students showed improvements in the specific elements of algebra, logic, pattern recognition, and sequence identification, the authors of the study attributed the net declines largely to components of tasks that "involved recall of facts or simple calculations"[17] with "substantial" losses on multiplication and addition facts.[18] There were no changes between 2005 and 2009.

While there were no performance differences for Year 8 students between 2001 and 2005, net performance masked differences in individual tasks. Year 8 students in 2005 were less proficient with facts and simple problems, and showed no differences in the other areas between 2001 and 2005. Between 2005 and 2009, there were no differences overall, but there was a substantial decline in multiplication problems.[19] Researchers assessed the methods students used to calculate answers in 2009, and attributed the decline largely to a move away from the vertical column method.

> [Problems occurred] particularly where computation involved carrying or where both numbers included two or more digits. Strategy explanations show a major change from vertical (algorithmic) strategies to horizontal strategies.[20]

15 Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 9 Students' Mathematics Achievement in 2010/11," op. cit., p. 29.

16 Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 5 Students' Mathematics Achievement in 2010/11," op. cit.

17 Lester Flockton, Terry Crooks, Jeffrey Smith and Lisa F. Smith, "Mathematics Assessment Results 2005," National Education Monitoring Project (NEMP) Report 37 (Dunedin: Educational Assessment Research Unit, University of Otago, 2006), p. 3.

18 Terry Crooks, Jeffrey Smith and Lester Flockton, "Mathematics Assessment Results 2009," National Education Monitoring Project (NEMP) Report 52 (Dunedin: Educational Assessment Research Unit, University of Otago, 2010), p. 3.

19 Ibid., p. 3.

20 Ibid., p. 36.

While there were no changes for Year 8 students between 1997 and 2007, there was a small improvement for Year 4 students, but this was "constrained by a drop in performance on tasks requiring quick recall or derivation of number facts".[21]

For measurement tasks, there were very small gains between 2001 and 2005 for both Year 4 and Year 8 students, and a decrease between 2005 and 2009 for Year 8 students.[22]

CREATIVE KIWIS VS ASIAN ROTE LEARNERS

In TIMSS 2011, New Zealand's Year 5 students placed 30th internationally, outperforming only 16 countries. New Zealand's mean score was 486, between the 'intermediate international benchmark' of 475 and the 'international scale centre point' of 500.[23]

The mean score (488) for New Zealand's Year 9 students in TIMSS 2011 was similar to the Year 5 mean score (relative to what is expected at that age) but "significantly lower than the TIMSS scale centre point" and "lower than the mean score of 14 countries including all the other English-speaking countries who participated".[24]

In PISA 2012, New Zealand's 15-year-olds ranked 18th internationally – similar to their counterparts in eight countries, and higher than their counterparts in 39 countries.[25]

DO SURVEYS MEASURE WHAT THEY ARE SUPPOSED TO MEASURE?

A concern about international student assessment surveys is that they may not reflect what children are learning in individual countries. TIMSS researchers have matched question items to curriculum content in different countries to "ascertain the level to which the results might change for New Zealand if only questions judged appropriate were included in the tests".[26]

Even when only including TIMSS items covered in the New Zealand Curriculum for Year 5 students, "the average New Zealand student would have got less than half the items correct".[27] For Year 5 students, 31 countries still performed better than New Zealand in *just* the items selected that match the New Zealand Curriculum. A similar pattern can be seen for Year 9 students.

The TIMSS report also notes that though 94% of the TIMSS questions were appropriate for Year 9 curriculum expectations, only about 20% of Year 9 students were working at that level of the curriculum.[28] This is likely because curriculum levels in New Zealand do not necessarily align with year levels at primary school.

The top performers in TIMSS for both Year 5 and Year 9 students were Singapore, South Korea, Hong Kong, Taiwan and Japan,[29] and the top performers in PISA for 15-year-olds were Shanghai, Singapore, Hong Kong, Taiwan and South Korea.[30] The Asian tigers consistently do well in maths.

21 Ibid., p. 3.

22 Ibid., p. 36.

23 Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 5 Students' Mathematics Achievement in 2010/11," op. cit., p. 27.

24 Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 9 Students' Mathematics Achievement in 2010/11," op. cit., p. 14.

25 Steve May, Saila Cowles and Michelle Lamy, "PISA 2012: New Zealand Summary Report," op. cit.

26 Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 5 Students' Mathematics Achievement in 2010/11," op. cit., p. 27.

27 Ibid.

28 Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 9 Students' Mathematics Achievement in 2010/11," op. cit.

29 Ina V.S. Mullis, Michael O. Martin, Pierre Foy and Alka Arora, "TIMSS 2011 International Results in Mathematics," op. cit.

30 OECD, *PISA 2012 Results: What Students Know and Can Do*, op. cit.

So how do New Zealand students perform in the different cognitive domains compared to their counterparts in the top Asian countries?

In TIMSS 2011, New Zealand's Year 5 students were slightly stronger in *applying* (with a mean score of 490) and *reasoning* (490) than *knowing* (476).[31] The pattern was similar for Year 9 students, although differences were not statistically significant.[32]

Students in top-performing countries, by contrast, showed the opposite pattern, with higher scores in *knowing* than *applying* and *reasoning* for Year 5 students (Year 9 students in the top countries showed similar scores across the cognitive domains). Year 5 students in Singapore (the top-performing country), for example, had mean scores of 629, 602 and 588 for *knowing*, *applying* and *reasoning*, respectively, and 617, 613, and 604, respectively, for Year 9 students.[33]

In PISA 2012, New Zealand's 15-year-olds were stronger in *interpreting* (511) than *formulating* (496) and *employing* (495).[34] Again, top-performing countries showed the opposite pattern, with a relative strength in *formulating*. Singapore's 15-year-olds' mean scores were 555 in *interpreting*, 582 in *formulating*, and 574 in *employing*.[35]

At face value, these findings seem to support a commonly held belief that New Zealand students are better at *applying* their knowledge than simply *knowing* 'stuff' and regurgitating it.

However, the numbers don't support this argument. In TIMSS 2011, New Zealand's Year 5 students performed worse than their counterparts in 28 countries in *applying*, and 29 countries in *reasoning*. New Zealand's Year 5 students are particularly weak in *knowing*, with 32 countries outperforming New Zealand in that domain.[36] New Zealand's Year 9 students performed similarly across the three domains and gained similar international rankings in each of the domains.[37] In PISA, though, New Zealand students' relative strength is in *interpreting* and top-performing countries' students' in *formulating*; still, 17 countries outperform New Zealand in *interpreting*.[38]

In other words, students in the top-performing Asian countries are not only better able to recall basic maths facts, but they are also better at applying those facts to solve novel problems. Knowing the basic maths facts is not sufficient for doing well on these tests, but it is necessary.

SUMMING IT UP

Despite indications of improving performance in the late 1990s, maths abilities among New Zealand students have flatlined or declined, and there are increasing proportions of students well behind international standards. Fortunately, while performance has not declined back to the mid-1990s levels, and New Zealand students have improved in some areas, their potential seems to be constrained by a lack of adequate knowledge of basic maths facts and processes. Chapter 2 analyses the changes in the way maths has been taught since 2000, when maths performance started declining.

THE NEW ZEALAND INITIATIVE

31 Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 5 Students' Mathematics Achievement in 2010/11," op. cit., Table 1.5, p. 30.

32 Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 9 Students' Mathematics Achievement in 2010/11," op. cit., Table 1.5, p. 28.

33 Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 5 Students' Mathematics Achievement in 2010/11," op. cit., Table 1.5, p. 26.

34 OECD, *PISA 2012 Results: What Students Know and Can Do*, op. cit., Tables 1.2.7, 1.2.1.0, 1.2.1.3, pp. 315, 319, 323.

35 Ibid.

36 Calculated from Ina V.S. Mullis, Michael O. Martin, Pierre Foy and Alka Arora, "TIMSS 2011 International Results in Mathematics," op. cit., Exhibit 3.3: Achievement in Mathematics Cognitive, p. 148.

37 Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 9 Students' Mathematics Achievement in 2010/11," op. cit., Table 1.5, p. 28.

38 OECD, *PISA 2012 Results: What Students Know and Can Do*, op. cit., Tables 1.2.7, 1.2.1.0, 1.2.1.3, pp. 315, 319, 323.

CHAPTER TWO
TOO MANY STRATEGIES, NOT ENOUGH FACTS

In 2013, food writer and parent Allyson Gofton lamented in the *New Zealand Herald* that her 10-year-old son was being taught seven strategies for multiplication, and that his teachers said "his understanding of the strategy was more important than the answer".[39]

She contrasts this with how he learned mathematics in France,[40] where her family spent some time.

> The kids here [in France] learn one way and one way only. They set out their maths work differently, they work on graph paper, they show their workings in an orderly manner, anything less is not accepted. It's easy to follow and yes it has to be right... Last week my son got 100 per cent in maths in long division – he was rapt. All done by hand and with a time limit. In a subject that he hated at home, which he now loves. He is so proud of himself. And we cannot believe the difference in his attitude to maths.[41]

Gofton's comments reflect concerns and confusion among New Zealand parents about the way maths is now taught. Despite millions spent on the Numeracy Project, which has changed the way maths is taught in primary schools, New Zealand has seen little progress in maths since the programme was rolled out.

THE HISTORY OF THE NUMERACY PROJECT

The first Trends in Mathematics and Science Study (TIMSS) results in 1995 showed New Zealand students faring worse than expected in maths internationally. However, New Zealanders bemoaning the state of maths education was not new even then. In 1997, Howard Fancy, then Secretary for Education, stated in a broadcast to schools:

> Indeed, the mathematics results are very similar to earlier studies. The Second International mathematics Study (1980–1982) [the predecessor study to TIMSS] also showed that New Zealand students were below international means in number and measurement. This suggests that we have an endemic weakness in these areas.[42]

39 Allyson Gofton, "Do the maths – NZ strategy wrong," The New Zealand Herald (9 April 2013).

40 Comparisons with France on primary school level maths achievement are not possible as France does not participate in TIMSS in Year 5 (France outperformed New Zealand in Year 9 in 1994). France, however, was ranked two places behind New Zealand in PISA 2012 with 15-year-olds, and was well behind New Zealand in every other year PISA was administered.

41 Allyson Gofton, "Do the maths – NZ strategy wrong," op. cit.

42 Ministry of Education, "Maths and Science Taskforce," Education Gazette 76:15 (Wellington: 1 September 1997).

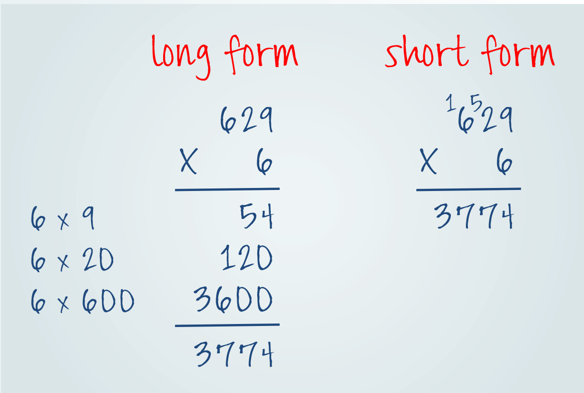
MATHEMATICAL TOOLS

Basic facts (like times tables or the knowledge that 50% = 0.5 = 1/2) can be rote learned. It is possible to know automatically that 7 x 3 = 21 without understanding what the numbers 7 and 3 represent, nor the concept of multiplication (seven groups of three), but this alone is not desirable.

Algorithms in the context of learning maths are (usually) efficient written methods for calculating answers to mathematical questions. For example, below is a multiplication algorithm to calculate 629 x 6. Both long and standard forms are shown. Again, it is possible that a child could learn the step-by-step method without understanding the context of the question (Sarah earned $629 each week for 6 weeks. What was her total take home pay?), or understanding how the numbers work. Children need to know place value to carry out these algorithms with understanding, and it is also possible that these tasks help form and strengthen understanding of place value.

Strategies are the different ways children conceptualise and solve maths problems mentally.

The traditional written algorithms can also be thought of as one type of strategy.



At the time of the first TIMSS results in 1995, momentum was building to improve teacher capability in maths instruction. A professional development (PD) programme ran from 1992 and 1995 in 1,700 schools[43] with Year 3 teachers[44] at a total cost (including for a science PD programme in 1,300 schools) of $15.5 million.[45]

TIMSS 1997 did not show any statistically significant improvement from 1995 – New Zealand students were still way behind their international counterparts. Responding to this in 1997, then Minister of Education Wyatt Creech of the National-led government formed a taskforce to improve maths (and science) performance. According to Vince Wright, who ran the Numeracy Project over its 10-year period, policymakers at that time were encouraged by improvements in the smaller PD programmes in the 1990s, and began searching for a bigger solution for scaling up some of the successes attributed to the PD programmes.

The taskforce made several recommendations: increasing teachers' confidence, skills and knowledge in science and maths instruction, and producing curriculum materials and school-based PD for teachers to accompany those materials.[46]

In 1999, policymakers started looking for an international model of numeracy development that could be rolled out across New Zealand's entire primary school system. In 2000, Australia's 'Count Me In Too' programme in New South Wales was adapted for New Zealand and piloted in around 80 schools.[47] Following the pilot, then Minister of Education Trevor Mallard of the Labour-led

43 Ibid.

44 Andrew Laxon, "Poor new-maths figures start with teachers: expert," The New Zealand Herald (16 March 2015).

45 Ministry of Education, "Maths and Science Taskforce," op. cit.

46 David Vannier, "Primary and Secondary School Science Education in New Zealand (Aotearoa) – Policies and Practices for a Better Future" (Wellington: Fulbright New Zealand, August 2012).

47 Ministry of Education, "Findings from the New Zealand Numeracy Development Projects" (Wellington: Ministry of Education, 2009), p. 1.

government rolled out the Numeracy Project in 2001 at a cost of $70 million.[48]

The Numeracy Project was in full effect from 2001 to 2005. Contracted university teams spent time in the 1,700 primary schools in New Zealand, conducting workshops, providing diagnostic classroom observation and feedback, and conducting follow-up workshops. The programme was both widespread and intensive. Every primary school teacher in the country went through a PD programme in numeracy teaching.[49]

Teachers received 12 to 13 hours of PD in the first year and 6 to 7 hours in the second year.

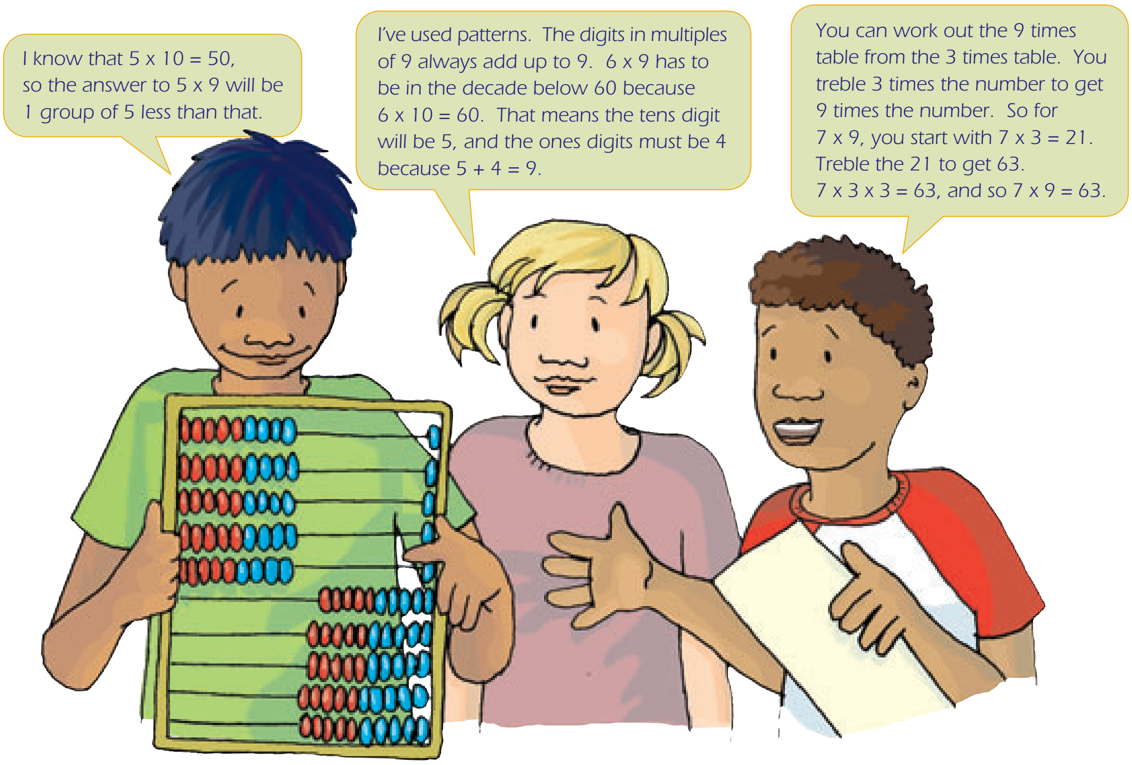
The Numeracy Project was an "initiative to introduce teachers to a new approach to the teaching of mathematics" and to encourage children "to learn a range of different ways to solve problems and to choose the most appropriate one for each problem"[50] (see Figure 4).

Even after the Numeracy Project was ended in 2009 due to funding constraints, its philosophy for teaching maths continues – many of the ideas underpinning the Numeracy Project have made their way into the 2007 National Curriculum; Numeracy Project teaching resources are still used; and many Numeracy Project facilitators now conduct PD for teachers under current PD delivery mechanisms.

Figure 4. Newer multiple-strategy methods of learning maths

Activity One

Rewi, Caitlin, and Obeda all have different strategies for working out their 9 times table:



Source: Ministry of Education, "Easy Nines," Website.

48 New Zealand Parliament, "Numeracy-Development Project: Questions to Hon Steve Maharey (Minister of Education), Hansard 633 (Wellington: House of Representatives, 30 August 2006), p. 4965.

49 Andrew Laxon, "Poor new-maths figures start with teachers: expert," op. cit.

50 Ministry of Education, "What is the Numeracy Project?" Website

A HISTORY OF CURRICULUM CHANGE

The introduction of the Numeracy Project coincided with general ideological changes about how maths should be taught, as revealed by an analysis of curriculum changes over time. Before 1993, New Zealand's curriculum was in the form of syllabuses by subject area, in various iterations between 1961 and 1986. A National Curriculum was released in 1993[51] and updated in 2007.

Three iterations of the primary school maths curriculum – *Mathematics: Infants to Standard 4* (1969); *Mathematics in the New Zealand Curriculum* (1992); and *The New Zealand Curriculum/Te Mauratanga o Aotearoa* (1997) – were compared for this report.

The 1969 curriculum for primary school (up to Standard 4, or Year 6 today) included not only the importance of developing confidence in maths and "positive attitudes towards the subject", but also "a mastery of the basic facts in addition, subtraction, multiplication and division". Even back then, the curriculum stated that memorisation was not enough by itself, and discouraged "memorisation of facts through formal drills before meanings have been established".[52]

> Throughout the syllabus the view is taken that the mastery of the basic facts of addition, subtraction, multiplication and division is an important feature of the study of numbers. The ability to recall from memory should not be regarded as the end point in the study of number relationships but, in the interest of efficient computation and for the purposes of everyday living, these basic facts should be known.[53]

By 1992, the *Mathematics in the New Zealand Curriculum* had a much different emphasis. It seems to reflect a changing mindset of maths as a vehicle for practicing problem solving skills rather than as a set of tools for problem solving:

> Real life problems are not always closed, nor do they necessarily have only one solution. Determining the best approximation for a solution, and finding the optimum way of solving a problem when several approaches are possible, are skills frequently required in the workplace.
>
> Students need frequent opportunities to work with open-ended problems. The solutions to problems which are worth solving seldom involve only one item of mathematical understanding or only one skill. Rather than remembering the single correct method, problem solving requires students to search the information for clues and make connections to the various pieces of mathematics and the other knowledge and skills which they have learned. Such problems encourage thinking rather than mere recall. Closed problems, which follow a well-known pattern of solution, develop only a limited range of skills. They encourage memorisation of routine methods rather than consideration and experimentation. While fluency with basic techniques is very important, such routines only become useful tools when students can apply them to realistic problems.[54]

In 2012, Fulbright scholar David Vannier, who researched primary level science education policy, noted the shift in maths instruction in New Zealand in the mid-1990s from "a traditional, memorisation-based approach to a focus on enabling students to understand the concepts behind mathematical thinking".[55]

Though the 1992 curriculum still emphasised the importance of basic techniques, it communicated a

51 Ministry of Education, "History of Curriculum Development," Website.

52 Department of Education. "Mathematics: Infants to Standard 4" (Wellington: 1969), p. 2.

53 Ibid., p. 5.

54 Ministry of Education, Mathematics in the New Zealand Curriculum 1992 (Wellington: 1992).

55 David Vannier, "Primary and Secondary School Science Education in New Zealand (Aotearoa), op. cit., p. 39.

touch of disdain for standard written methods and basic learned facts:

> Teachers should avoid carrying out tests which focus on a narrow range of skills such as the correct application of standard algorithms. While such skills are important, a consequence of a narrow assessment regime which isolates discrete skills or knowledge is that students tend to learn that way. Mathematics becomes for them a set of separate skills and concepts with little obvious connection to other aspects of learning or their world.[56]

Similar to the 1969 curriculum, the 1992 curriculum said rote learning is not enough without the conceptual connection. But it is easy to see how the above comments could be interpreted by teachers as suggesting algorithms and facts are no longer important.

In the 2007 curriculum, the teacher's focus was shifted towards the learner and away from "a prescriptive list of content to be delivered" not only for maths but all subjects.[57] Communications seem to relegate algorithms and rote learning as relics of history. In a 2009 compendium of research papers on the Numeracy Project, Derek Holton, Emeritus Professor at the Department of Mathematics and Statistics at the University of Otago, said:

> An emphasis on letting students explore and absorb number sense, rather than teaching them learned algorithms without any understanding, seems to be the right way ahead for students to gain an understanding of number and, possibly more importantly, of liking and feeling comfortable with mathematics itself. At all costs, we should ensure that we never return to the hundreds of algorithms that have made mathematics a wasteland full of the rote learning of incomprehensible rules.[58]

Today, the nzmaths.co.nz website, a depository of maths curriculum materials for teachers, even questions the need for the written form. Mathematics consultant Audrey Tan, who runs the campaign 'Bring Back Column Addition to New Zealand's Early Primary Maths Curriculum', found the following question and answer on the FAQ section of the site in early 2013:

> Q: When should I start teaching the written form?
>
> A: Teachers should debate whether they will introduce the written form at all.

SOUL SEARCHING

In a 2013 interview to the *New Zealand Herald*, Wright acknowledged that the poor performance of Kiwi students in national and international maths tests over the past 10 years had caused a "lot of soul searching" in education circles.[59]

Indeed, the Numeracy Project is commonly blamed for New Zealand's declining performance in mathematics in primary schools. The history of curriculum changes illustrate a general attitudinal shift towards more relational understanding in maths education, with less emphasis on instrumental understanding. Whether the Numeracy Project was the mirror or maker of these attitude changes is difficult to know, but it is safe to say that it has not returned results as intended. And, as shown below, these attitudes tend to play out in the way maths is taught in the classroom.

REASONING WITHOUT FACTS

TIMSS 2011 showed that teachers of Year 5 and Year 9 students were far less likely (12% and 19%, respectively) compared to the international average

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56 Mathematics in the New Zealand Curriculum 1992, op. cit.

57 David Vannier, "Primary and Secondary School Science Education in New Zealand (Aotearoa), op. cit., p. 10.

58 Ministry of Education, "Findings from the New Zealand Numeracy Development Projects," op. cit. p. 2.

59 Andrew Laxon, "Poor new-maths figures start with teachers: expert," op. cit.

(37% and 45%) to require students to memorise rules, procedures and facts in most or all lessons.[60]

It is even more telling to compare New Zealand with the top-performing countries on these measures (see Figure 5). While the figure shows no consistent pattern among the top five countries, it does show that New Zealand teachers, by comparison, put a much greater emphasis on encouraging children to explain their answers, and much less emphasis on memorising facts, procedures, and rules.

Survey differences between each round of TIMSS mean it is impossible to make comparisons over *time* to explore shifts in the emphasis on explaining answers. Nonetheless, given the comparison countries in figure 5 are better in the domains of *knowing*, *applying* and *reasoning* (see Chapter 1), it is reasonable to suggest that New Zealand teachers, in general, are spending too much time teaching both Year 5 and Year 9 children how to reason mathematically, and too little time teaching children the basic facts needed for reasoning.

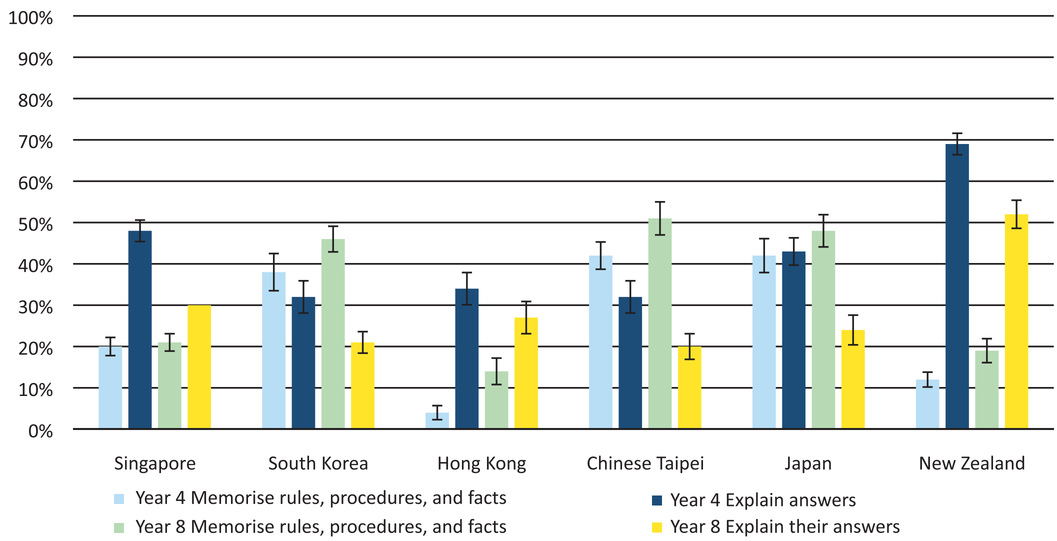
AN EITHER/OR SITUATION?

Former Deputy Headmaster of the Cathedral Grammar School in Christchurch, Malcolm Long, laments the Ministry of Education's disdain for "traditional" mathematics:

> We can have no beef with the [the elevation of mental computation] – bring on greater mental acuity in mathematics – but in the put-down of "rules" we should hear warning bells about where [the Numeracy Project] is leading. Mathematics, after all, is a subject with many rules which make it an international language to explain the real world. Learning these rules is actually what makes mathematics understandable, and being able to write them in a way that other people can understand is a vital part of real mathematics.[61]

Developing a conceptual understanding is essential, and even the 1969 curriculum discouraged "memorisation of facts through formal drills before meanings have been established".

Figure 5. Percentage of students whose teachers require students to *memorise facts* and *explain answers* in most classes



Source: Calculated from Ina V.S. Mullis, Michael O. Martin, Pierre Foy and Alka Arora, "TIMSS 2011 International Results in Mathematics" (Boston: TIMSS & PIRLS International Study Center Lynch School of Education, Boston College, 2012), Exhibit 3.3: Achievement in Mathematics Cognitive, pp. 398–400.

60 Ina V.S. Mullis, Michael O. Martin, Pierre Foy and Alka Arora, "TIMSS 2011 International Results in Mathematics," op. cit., Exhibit 3.3: Achievement in Mathematics Cognitive, p. 398–400.

61 The Cathedral Grammar School, "Another unfortunate experiment – the Numeracy Project," Headmaster's Blog.

But also, obtaining the correct answer as efficiently as possible, with the smallest amount of time and brain power, opens up time and cognitive energy for students to undertake more complex tasks to deepen their conceptual understanding of maths.

Indeed, both Long and Tan are in favour of mental computation, but not as a substitute for the traditional written form. That the Ministry's maths website encourages debate on whether the written form should be used at all is particularly concerning. The point is, maths education should not be characterised as either 'inchworm' or 'grasshopper' (see sidebar). Gaining fluency in the traditional written algorithms, plus automatically being able to recall simple facts, will help rather than hinder deeper conceptual mathematical understanding.

Wright, reflecting on a comment that teachers these days do not seem to place as much emphasis on learning the times tables, says:

> I don't know where that came from. The curriculum still maintains that is important and I'm perplexed to know where the message comes from. It might be more tied to the notion in the modern world, you've got Google at your fingertips, look it up, or use a calculator. I'm wondering if it's a bit more of that. At a national level, we tried really hard for people to understand the necessity of knowing stuff. There are assessment tools online. You need information. I don't think this is a New Zealand phenomenon.[62]

He is quick to point out that learning concepts at the expense of the basics was never the intention of the Numeracy Project. Underscoring the critical importance of both knowledge and strategies, he says, "They're polarised [by others] but they do work in harmony".[63]

Yet some of the quotes throughout this chapter show contempt for rote-learned facts and the

62 Vince Wright, ex-Ministry of Education, personal interview (16 December 2015).

63 Ibid.

INCHWORMS OR GRASSHOPPERS?

One way to conceptualise the older and newer ways of teaching maths is to think of them as *inchworm* and *grasshopper* methods (noting that both are important and they need not be dichotomised).

Inchworm learning:

- Prescriptive
- Factual
- Written problem solving
- Formulaic
- Procedural
- Single method
- Exact
- Analytical

Grasshopper learning:

- Intuitive
- 'Big picture'
- Estimative
- Patterns
- Verification
- Mental problem solving
- Flexible methods
- Numbers adjusted for calculation
- Investigative

Source: Steve Chinn and Richard Ashcroft, *Mathematics for Dyslexics: A Teaching Handbook* (2nd ed.) (London: Whurr Publishers, 1998).

Another conceptualisation is 'relational' and 'instrumental' understanding:

Instrumental understanding "involves the learning of mathematical rules and being able to carry them out effectively".

Relational understanding is "having the ability to see the connections and relationships between numbers and areas of mathematics and to be able to apply them to new situations, 'knowing what to do and why'".

Source: Ashley Compton, Helen Fielding and Mike Scott, *Supporting Numeracy: A Guide for School Support Staff* (2007).

written form. Whether the communications from the Ministry of Education and education researchers were intended to create anti rote-learning attitudes is difficult to know, but the attitude has certainly carried through to maths teaching.

SUMMING IT UP

Regardless of whether the Numeracy Project is the mirror or maker of anti-algorithm and anti-rote learning attitudes, children are not learning the basic building blocks in maths. Rather than striking a good balance between instrumental learning and relational learning, and enabling the two to build on each other, they tend to be falsely dichotomised. They should work in tandem.

The written form, once mastered, frees up mental energy for accessing higher levels of mathematical thinking.

The Ministry states that knowledge is still important, but sends conflicting messages. One of the achievement objectives of the National Curriculum, for example, for level two, is to "know the basic addition and subtraction facts".[64]

However, some of the language from educational researchers outlined in this chapter reflects a more disparaging view of instrumental learning and there are conflicting messages from the Ministry. Part of the issue is that good intentions at a national policy or research level can be interpreted in wildly different ways at the school level.

64 The New Zealand Curriculum, "Mathematics and Statistics," Website.

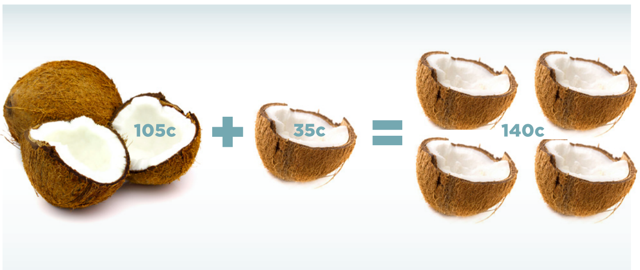
BOX 2. STREET MATHS VS SCHOOL MATHS

Coconuts and cruzeiros offer some clues to the differences between 'relational' and 'instrumental' teaching and learning of maths.

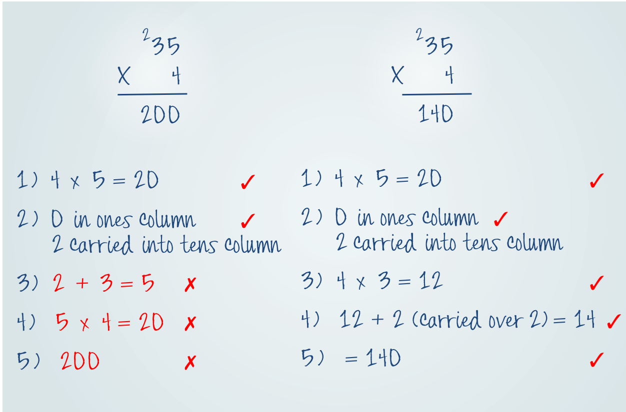
In 1993, researchers in Brazil observed children working as market traders. The researchers documented how the children applied mathematics to transactions, compared with how they learned maths in school.[65]

The question the researchers put to the children was: how much do four coconuts, which each cost 35 cruzeiros, cost altogether?

A customer came to the counter with four coconuts. The researchers observed that a 12-year-old trader used his automatic knowledge that three coconuts cost 105 cruzeiros. He then rounded the cost of a coconut down to 30 cruzeiros to make the calculation easier, to get to 135, then added the remaining 5 cruzeiros.



In school, the problem was presented and calculated differently by the 12-year-old using an algorithm to calculate 35 x 4. The calculations below show the wrong steps he took (on the left) compared to the correct way of using the algorithm to obtain the answer (on the right).



The authors of the article explain the disparity:

> The study finds many similar examples from other children who worked as market traders showing the interesting situation where children could calculate when the mathematics was presented in a real-life situation which they could relate to (street mathematics) but not when presented in a standard arithmetic form.[66]

It would be easy to conclude from such studies that maths should be taught with word problems applicable to real-world contexts, or indeed, why some teachers might have developed an attitude that algorithms are meaningless and do not reflect real maths understanding. However, learning the multiplication algorithm is still useful for a number of reasons.

First, it serves as a quick method for multiplying more complex numbers. While the 12-year-old boy can work out the price of four coconuts, it might be more difficult to work out, using his method, the price of, say, 84 coconuts. The algorithm learned at school would be handy if he can understand

65 Terezinha Nunes, Analucia Dias Schliemann and David William Carraher, Street Mathematics and School Mathematics (New York: Cambridge University Press, 1993).

66 as cited in Ashley Compton, Helen Fielding and Mike Scott, *Supporting Numeracy: A Guide for School Support Staff*.

that the numbers 35 and 4 represent cruzeiros and coconuts, respectively. The boy starts to understand 1, 10, 100 columns and so on, and this concept is a precursor to further and more complex mathematical knowledge. Practising the manipulation of symbols more generally serves as a precursor to further and more complex mathematical concepts and skills. Finally, he learns that in maths, there are correct answers that can be arrived at using efficient methods.

It is entirely appropriate, and in fact necessary, for teachers to help students understand mathematical concepts by linking what they are learning to their everyday world – from the abstract to the concrete. The 1992 New Zealand National Curriculum, for example, states:

> A child's concept of "four" could be enriched by discussing the number of wheels on a car, legs on a table, or edges on a piece of paper... similarly, secondary students could be focussed on the concept of "rate of change" by discussing, for example, that younger people grow faster than older people, or by discussing the slope changes on nearby hills.[67]

But it is also vital that teachers link everyday concepts to the abstract through teaching children the written methods, which are in most cases quick and efficient ways of working out answers. It should not be a matter of discarding written methods, but linking them to real situations that children can grasp.

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67 *Mathematics in the New Zealand Curriculum 1992*, op. cit., p. 13.

CHAPTER THREE

A CONSTANT IN THE EQUATION: TEACHERS STRUGGLE WITH MATHS

Up to half New Zealand's primary teachers may not have enough maths knowledge to teach children properly under new methods.[68]

The Numeracy Project may have in part failed to lift performance nationally because many primary school teachers may not be mathematically proficient to teach the newer methods of maths.

CAN TEACHERS DO MATHS?

The little research on New Zealand primary school teachers' maths abilities suggests deep gaps. In 2010, mathematics education researcher Jenny Young-Loveridge tested 125 future primary-school teachers at the end of their Bachelor of Teaching degrees on their maths abilities. A selection of test questions is shown in Figure 6.[69]

Figure 6. Example maths questions

Q 1

$$\frac{7}{18} + \frac{1}{9} = \frac{?}{?}$$

Q 2

Place these fractions in order from smallest to largest.

$$\frac{1}{2} \quad \frac{1}{4} \quad \frac{7}{8} \quad \frac{12}{10} \quad \frac{3}{5} \quad \frac{10}{8} \quad \frac{1}{10} \quad \frac{3}{4}$$

Q 3

Which is the largest number?

A. 29 + 0.8 B. 29 x 0.8 C. 29 ÷ 0.8 D. 29 – 0.8

Only 62% of the about-to-be-teachers obtained the correct answer for Q 1 (the most common mistake was adding the denominators and numerators); 58% for Q 2, and 33% for Q 3 (mistakenly applying a rule for whole numbers to part numbers: that multiplying makes a number bigger and dividing makes a number smaller). Young-Loveridge rightly concluded that "the numbers of students who were unable to successfully complete particular fractional number tasks presented to them was disappointing".[70]

It may be that teacher maths abilities are even more important for the newer methods of teaching maths introduced with the Numeracy Project. In the 'olden days', teachers may have relied on their own rote-learned facts and processes, not needing a deeper conceptual understanding of maths. But simple maths operations are no longer enough. Today's emphasis on understanding mathematical concepts deeply rests on teachers having that deeper understanding themselves.

KNOWING MATHS IS IMPORTANT…

I've worked with hundreds of teachers and does it make a difference what maths they know? Yes.
— Vince Wright, ex-Ministry of Education, personal interview (16 December 2014).

The literature reports widespread agreement that teachers should have solid mastery of the content in the subject to be taught.
— Trends in Mathematics and Science Study (TIMSS) 2011 International Results in Mathematics (2012, p. 282)

68 Andrew Laxon, "Poor new-maths figures start with teachers: expert," op. cit.

69 Jenny Young-Loveridge, "Two Decades of Mathematics Education Reform in New Zealand: What Impact on the Attitudes of Teacher Education Students?" In Conference Proceedings, 33rd Annual Conference of the Mathematics Education Research Group of Australasia (2010), p. 710.

70 Ibid. p. 711.

Indeed, a robust body of evidence shows that teachers' general "intellectual resources" strongly influence student learning.[71] In particular, teachers' general knowledge and maths-specific knowledge both predict student achievement in maths.[72] Several studies show that teacher scores on maths tests predict student scores. Jurgen Baumert and Mareike Kunter, in a review of teacher maths knowledge and student progress, say an "insufficient understanding of mathematical content limits teachers' capacity to explain and represent that content to students in a sense-making way, a deficit that cannot be offset by pedagogical skill".[73]

… BUT IT IS NOT ENOUGH

Based on their study of 16,000 future teachers, Sigrid Blomeke, et al. concluded that self-reported achievement in maths and the number of years teachers had taken maths in their own schooling days predicted teachers' maths ability, but did not help with their knowledge of how to teach maths.[74] The ability to *teach* maths to children is just as critical as *knowing* maths to student achievement.[75] Heather C. Hill, Brian Rowan and Deborah Ball cite research showing "what teachers would need to understand about fractions, place value, or slope, for instance, would be substantially different from what would suffice for other adults".[76]

Hill, et al. also found that primary school teachers' abilities to represent mathematical concepts to students predicted student achievement in maths, even when controlling for other teacher and student variables related to achievement.[77]

MATHS DEGREES AND PERFORMANCE

Although teacher proficiency in maths (and maths *teaching*) is critical for student learning in maths, primary school teachers having maths degrees would not necessarily lift student performance in maths.

Internationally, Year 5 students taught by teachers with a maths degree but not an education degree perform lower in maths.[78] In New Zealand too, maths achievement is not higher among students whose teachers have a primary education degree and a specialisation or major in maths (see Table 4). It should be noted, though, that only 15% of Year 5 students are taught by those with a maths degree (76% are taught by teachers with a major in primary education). This is not surprising given that teachers are typically generalists rather than specialists at the primary school level (although there is specialisation in some schools in Year 7 and Year 8).

Year 9 students show no differences in achievement, on average across all countries, depending on whether their teachers had maths majors.[79] Most Year 9 teachers did have a maths degree though (32% had a major in both maths and maths education, and 41% a major in maths),[80] probably

71 Heather C. Hill, Brian Rowan and Deborah Ball, "Effects of Teachers' Mathematical Knowledge for Teaching on Student Achievement," *American Educational Research Journal* 42:2 (2005), pp. 371–406.

72 Jaap Scheerens and Roel J. Bosker, "The Foundations of Educational Effectiveness," *International Review of Education* 45:1 (1999), pp. 113–120.

73 Jurgen Baumert and Mareike Kunter, "Teachers' Mathematical Knowledge, Cognitive Activation in the Classroom, and Student Progress," *American Educational Research Journal* 47:1 (2010), pp. 133–180, 138.

74 Sigrid Blomeke, Ute Suhl, Gabriele Kaiser and Martina Dohrmann, "Family Background, Entry Selectivity and Opportunities to Learn: What Matters in Primary Teacher Education? An International Comparison of Fifteen Countries," *Teaching and Teacher Education* 28:1 (2012), pp. 44–55.

75 Jurgen Baumert and Mareike Kunter, "Teachers' Mathematical Knowledge, Cognitive Activation in the Classroom, and Student Progress," op. cit.

76 Heather C. Hill, Brian Rowan and Deborah Ball, "Effects of Teachers' Mathematical Knowledge for Teaching on Student Achievement," op. cit.

77 Ibid.

78 Ina V.S. Mullis, Michael O. Martin, Pierre Foy and Alka Arora, "TIMSS 2011 International Results in Mathematics," op. cit., p. 283.

79 Ibid., p. 283.

80 Ibid., p. 283.

reflecting that these teachers also teach upper levels of the secondary school maths curriculum. Year 9 New Zealand students taught by teachers with a maths degree and a maths education degree do show significantly higher levels of achievement (see Table 5). However, it is difficult to draw meaningful conclusions from this data because there may be alternative explanations such as differences in the types of classes to which teachers with and without maths degrees are assigned.

Some research suggests teacher mastery of maths matters more than having a maths degree. In 2013, an experimental study by the US Department of Education found that after one year, students of Teach For America (TFA) maths teachers (a training route into teaching) were 2.6 months ahead in maths compared to students of maths teachers who came through traditional teaching routes.[81] Interestingly, while TFA teachers were less likely than traditional teachers to have a maths degree, they scored higher on a test of maths knowledge.

Aside from Young-Loveridge's small study, there is little research on the maths competency of New Zealand's primary school teachers, and no comparable international data. It becomes necessary then to look for likely proxies for teacher mathematical abilities – how difficult (selective) it is to enter teacher education and graduate from teacher training, and how much teachers are paid relative to other professions.

Table 4. Percent of Year 5 students with teachers with different kinds of maths qualifications

Major in primary education and major (or specialisation) in maths		Major in primary education but no major (or specialisation) in maths		Major in maths but no major in primary education		All other majors	
Percent	Average achievement	Percent	Average achievement	Percent	Average achievement	Percent	Average achievement
15 (2.1)	480 (8.7)	76 (2.6)	488 (3.1)	0 (0.1)	–	9 (1.5)	488 (7.6)

Source: Ina V.S. Mullis, Michael O. Martin, Pierre Foy and Alka Arora, "TIMSS 2011 International Results in Mathematics" (Boston: TIMSS & PIRLS International Study Center Lynch School of Education, Boston College, 2012), Exhibit 7.3: Teachers Majored in Education and Mathematics, pp. 288–289.

Table 5. Percent of Year 9 students with teachers with different kinds of maths qualifications

Major in maths and maths education		Major in maths education but no major in maths		Major in maths but no major in maths education		All other majors	
Percent	Average achievement	Percent	Average achievement	Percent	Average achievement	Percent	Average achievement
29 (2.8)	505 (11.0)	5 (1.6)	492 (28.7)	37 (3.4)	490 (6.0)	30 (3.1)	471 (9.9)

Source: Ina V.S. Mullis, Michael O. Martin, Pierre Foy and Alka Arora, "TIMSS 2011 International Results in Mathematics" (Boston: TIMSS & PIRLS International Study Center Lynch School of Education, Boston College, 2012), Exhibit 7.4: Teachers Majored in Education and Mathematics, pp. 290–291.

81 Melissa A. Clark, et al., "The Effectiveness of Secondary Math Teachers from Teach For America and the Teaching Fellows Programs" (No. NCEE 2013-4015) (Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education, 2013).

TEACHER TRAINING

Attracting people to teaching with high levels of academic ability is critical for improving student achievement, particularly in maths. As The New Zealand Initiative's series of reports on teacher quality showed, student achievement in top-performing countries like Singapore and Finland is largely due to the quality of their teachers and the ability to attract the top cohort of graduates into teaching.[82]

Blomeke, et al.'s research shows opportunities to learn both maths content knowledge and maths pedagogical content knowledge during teaching preparation were highly predictive of teachers' maths abilities and maths-teaching abilities (see sidebar p.25). Some of the effects were mitigated when background maths ability was controlled for.[83] A meta-analysis, however, found more mixed results on teachers' subject preparation on subsequent student achievement.[84] The effects of maths preparation during teacher training may largely depend on the quality of that training.

Currently, there are no mandated minimum academic standards to be admitted to one of the 16 accredited Initial Teacher Education (ITE) courses in New Zealand for primary or secondary teacher education, aside from University Entrance. Most ITE courses require applicants to pass basic literacy and numeracy tests, but this requirement is not monitored nationally – nor is data collected on how applicants perform on these tests or the percentage of applicants admitted to ITE courses. Only the University of Otago has a test of maths competency as part of its Bachelor of Teaching. The New Zealand Teachers Council (NZTC) has been lacking in this area. It established *Graduating Teacher Standards* in 2007, which included 'Standard One: Graduating Teachers Know What To Teach', which includes both content knowledge and pedagogical content knowledge "appropriate to the learners and learning areas of their programme".[85] When ITE providers get their courses approved or reapproved by the NZTC, they must demonstrate that the courses will allow their graduates to meet these standards, but there seems to be no objective criteria by which the NZTC judges this.[86]

Typically, most Bachelor of Education (primary) courses in New Zealand include one maths teaching paper per year of study, but it is one small part of the overall curriculum of teacher education, only making up 8% and 17% of degree points, depending on the provider and the course. David Vannier, in his work on science education in New Zealand schools, noted concerns that primary education students are "receiving less and less coursework in science and are thus less prepared to teach it as part of the required curriculum"[87]. He estimated there are fewer than 8 hours of science teaching in ITE. The same could be true for maths instruction.

TEACHER PROFESSIONAL DEVELOPMENT

Meta-analyses show ongoing maths PD programmes influence student achievement.[88] New Zealand actually has high levels of teacher maths PD. In the TIMSS 2011 study, 72% of teachers of Year 5 students reported receiving maths content

82 John Morris and Rose Patterson, *World Class Education? Why New Zealand Must Strengthen Its Teaching Profession* (Wellington: The New Zealand Initiative, 2013); *Around the World: The Evolution of Teaching as a Profession* (2013); *Teaching Stars: Transforming the Education Profession* (2014).

83 Sigrid Blomeke, et. al., "Family Background, Entry Selectivity and Opportunities to Learn: What Matters in Primary Teacher Education?" op.cit.

84 Suzanne M. Wilson, Robert E. Floden and Joan Ferrini-Mundy, "Teacher Preparation Research: An Insider's View from the Outside," *Journal of Teacher Education* 53 (2002), pp. 190–204.

85 New Zealand Teachers Council, "Graduating Teacher Standards," Website.

86 Note that the NZTC is being disestablished and replaced by the Education Council of Aotearoa New Zealand (Educanz).

87 David Vannier, "Primary and Secondary School Science Education in New Zealand (Aotearoa), op. cit., p. 11.

88 Rolf K. Blank and Nina de las Alas, "Effects of Teacher Professional Development on Gains in Student Achievement" (Washington, DC: Council of Chief State School Officers, 2009).

UNPACKING THE TERMINOLOGY

A well-accepted typology of teacher knowledge, characterised by educational psychologist Lee Shulman in 1987, is the distinction between content knowledge, pedagogical content knowledge, and generic pedagogical knowledge.

Mathematics content knowledge (MCK) is maths knowledge and skills.

Mathematics pedagogical content knowledge (MPCK) is the knowledge of how to transform, represent and communicate maths knowledge to facilitate student learning.

Generic pedagogical knowledge (GPK) refers to knowledge of how students learn more generally.

In the late 1990s, educational researcher Deborah L. Ball and colleagues developed an instrument to measure both the MCK and MPCK required for teaching maths to primary school students. Hill, Schilling and Ball (2005) found that this multiple choice test is a valid measure of the knowledge required for teaching maths.

PD in the past two years, and 67% maths pedagogy PD. Only 2 out of 51 countries had higher levels of maths content PD than New Zealand, and five higher levels of maths pedagogy PD.[89]

However, teachers are now taught the newer style of teaching maths, which may explain declining student achievement in maths despite high levels of PD.

TEACHER PAY

Attracting people with high levels of maths ability is important for teaching maths, and the ability to attract those people depends on how much teaching pays compared to other professions. Teachers are generally paid on a time-served basis in New Zealand. Whether this, over and above the actual salary amount, influences the attraction and retention of those with maths skills is an important question for future research. This section simply looks at average salaries relative to other professions to provide some clues on the likely maths proficiency of those going into teaching. As the OECD points out:

> The propensity of young people to undertake teacher training, as well as of training teachers to enter or stay in the profession will be influenced by the salaries of teachers relative to those of other occupations requiring similar levels of qualification.[90]

Blomeke, et al. noted that this was a controversial issue and the evidence is mixed. Teachers are motivated by rewards other than pay, such as making a difference to the lives of young people. But whatever the intrinsic rewards of teaching, fewer people will be attracted to a profession if they can receive better compensation for their skills elsewhere.

DOES PAY MOTIVATE TEACHERS?

Evidence suggests a passion for working with young people is not enough for teaching maths. Blomeke, et al. tested three different types of motivations for going into primary school teaching:

1. subject-matter motives (tested with the statement “I love mathematics”);
2. extrinsic motivations (job security); and
3. altruistic motivations (working with young people).

89 Ina V.S. Mullis, Michael O. Martin, Pierre Foy and Alka Arora, “TIMSS 2011 International Results in Mathematics,” op. cit.

90 OECD, *Education at a Glance 2011: OECD Indicators* (Paris: OECD Publishing, 2011), p. 408.

Enjoyment of the subject of maths was associated positively with teachers' maths abilities and maths teaching abilities, while extrinsic motivations (job security) and altruistic motivations (working with young people) were negatively associated.

But maths education specialist Fred Biddulph found in 1999 that more than half the primary teacher education students in New Zealand had "deeply negative feelings and attitudes" towards maths.[91] It is safe to say these teachers do not love maths, and were probably attracted to teaching for the intrinsic rewards rather than the love of the subject.

RELATIVE SALARIES

The Ministry of Education has published annual Education Counts figures on total teacher salaries since 2001, and the total number of teachers since 2004. Using those figures, it is possible to estimate mean teacher salaries (see Table 6).[92]

The Education Counts data shows teacher salaries have increased by 29% since 2004. Part of this increase is likely due to the changing cohort of teachers (an ageing workforce) with more teachers at higher points on the salary scale, but is mostly due to higher salaries negotiated through collective bargaining, confirmed by cross-checking this data against teacher collective agreements back to 1998.

While teacher salaries have increased over time in raw terms, it is necessary to compare changes in teacher salaries relative to other professional occupations. An international study by the International Association for the Evaluation of Educational Achievement (IEA) compared teacher and scientist salaries,[93] but it is also useful to compare engineering, law and accountancy – professions to which teaching is typically compared.[94]

Analysis was carried out for this report using Linked Employer-Employee Data (LEED) from Statistics New Zealand, which provides salary data by industry. The LEED data is not available for teachers specifically, but it is available for the category 'school education'. This was compared with salaries

Table 6. Mean educator salaries in New Zealand (2004 to 2012)

2004	2005	2006	2007	2008	2009	2010	2011	2012
$52,286	$54,966	$55,911	$62,607	$64,170	$65,386	$66,567	$67,208	$67,553

Source: Compiled using data from Education Counts, "Teacher Salaries Funding to Schools 2001–2014. Teacher Salaries by School Type" and "Trend Analysis Time Series 2004–2012. Teacher Headcount by Designation (Grouped) and Gender in State and State Integrated Schools, as at April 2004 – 2012," Website.

Note: The figures include part-time teachers, so are not indicative of average full-time teacher salary. However, the same general pattern of increasing salaries over time is seen when analysed by full-time equivalent figures.

91 Jenny Young Loveridge, "Two Decades of Mathematics Education Reform in New Zealand: What Impact on the Attitudes of Teacher Education Students?" op. cit., p. 706.

92 Because there are some overlapping categories by school sector (e.g. primary schools that go up to Year 8 and secondary schools that start from Year 7), this analysis looked at aggregate figures. Education Counts splits the number of teachers by categories such as principals, senior management, teachers, etc. Again there is complexity behind these figures – many primary school principals, for example, also have teaching workloads. Thus, this analysis is really looking at educators as a wider category that includes school leadership.

93 Martin Carnoy, Tara Beteille, Iliana Brodziak, Thomas Luschei and Prashant Loyalka, "Teacher Education and Development Study in Mathematics (TEDS-M). Do Countries Paying Teachers Higher Relative Salaries Have Higher Student Mathematics Achievement?" (International Association for the Evaluation of Educational Achievement, 2009).

94 John Morris and Rose Patterson, *Around the World: The Evolution of Teaching as a Profession*, op. cit.

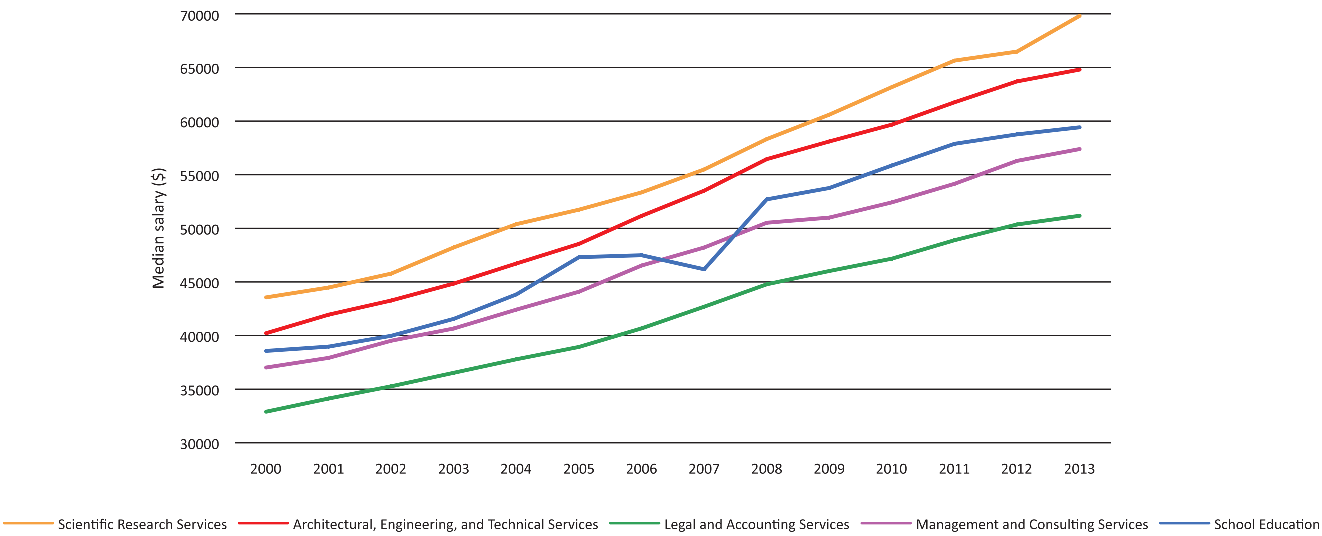
of other categories of professions that those with tertiary qualifications are likely to go into: scientific research services; architectural, engineering and technical services; legal and accounting services; and management and consulting services. The salary data for the 'school education' category reflects secondary and primary school education, and not only teachers but school leadership and support staff salaries. This should still be roughly comparable with the other occupational categories though. The 'legal services' category, for example, also includes management and administration staff. The data reflects both self-employment and wages and salary data, as these are not disaggregated in the quarterly LEED tables used for this analysis. Any single data point is unreliable as these figures include both part-time and full-time salaries, and a mix of professional and support staff salaries.

Median school education salaries have grown in line with the salaries of comparable occupations between 2000 and 2013 (see Figure 7). Though there was a dip between 2006 and 2007 for teachers, it corrected by 2008. 'School education' staff do not earn as much as architects, engineers and scientists, but more than those in management, consulting, legal and accounting services.

Although it seems teaching is a relatively lucrative profession compared with other high level professions like law and accounting, median starting salaries, which signal to potential teachers how highly teaching is valued compared to other degree-level professions, show a different picture (see Figure 8). LEED defines 'new hires' as those new to a particular place of employment, which captures new teachers as well as those who have switched schools, and data is available from 2001 to 2013. While it would be ideal to tease out brand new teachers from those switching jobs, it is still roughly comparable with the other occupational categories as they also include those brand new to the profession plus new hires.

2013 is an outlier – the drop here might be explained by particularly low turnover in that year, meaning that this data point captures proportionately more of those completely new to the profession, and proportionately fewer switching schools. Actual starting salaries for teachers (as opposed to 'School Education' salaries presented here) start at $45,796.[95]

Figure 7. Median salaries professional occupations (2000 to 2013)

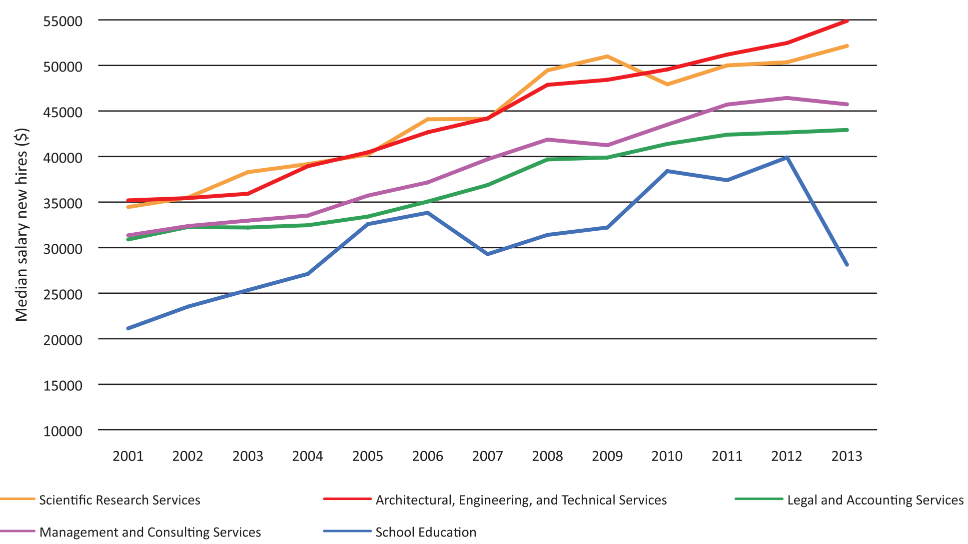


Source: Linked Employer-Employee Data, "Table 4: LEED Measures, By Industry" (based on ANZSIC06) (Wellington: Statistics New Zealand, Data Extracted 9 April 2015).

Notes: An important caveat is that this data includes both full-time and part-time salaries. There are likely more part-time teachers than part-time scientists or accountants, for example. The purpose of presenting this data is to show time trends in relative salaries.

95 John Morris and Rose Patterson, *World Class Education: Why New Zealand Must Strengthen Its Teaching Profession*, op. cit.

Figure 8. Median new hire salaries (2001 to 2013)



Source: Linked Employer-Employee Data, "Table 4: LEED Measures, By Industry" (based on ANZSIC06) (Wellington: Statistics New Zealand, Data Extracted 9 April 2015).

Teachers newly hired to schools earn less compared to new hires in other professional categories, but this has been consistent over time. Under the assumption that higher salaries are likely, at the margin to attract teachers with higher maths skills, this data suggests that teaching has not become any more or less likely to attract those with adequate maths competency for teaching maths, at least over the last 15 years.

This data on median teacher salaries and teacher salaries for new hires relative to other occupations shows that while teacher salaries have risen, they have stayed flat relative to other professions.

The OECD shows that internationally in 2011, primary, lower secondary, and upper secondary teachers earned 77%, 81%, and 85%, respectively, of the average salaries of those with the same level of education (tertiary).[96] Although teacher salaries increased in real terms between 1995 and 2009, most countries had declining teacher salaries "relative to GDP per capita during the 2000-2009 period".[97]

96 OECD, *Education at a Glance 2011: OECD Indicators*, op. cit. p. 406.

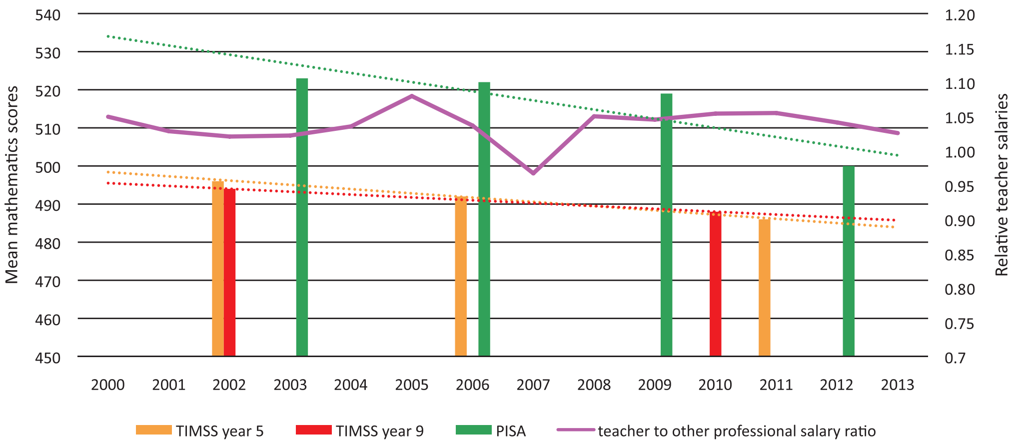
97 Ibid, p. 410.

New Zealand is unfortunately not included in the OECD report. To test whether relative teacher salaries have changed over time, a ratio of median school education salaries to other professional (the average of legal and accounting services, management and other consulting, scientific research, and architectural, engineering and technical services) was calculated for each year. This was compared to student achievement in maths as measured by the Programme for International Student Assessment (PISA) and TIMSS (see Figure 9).

There was no statistically significant change in the ratio of median teacher-to-other profession salaries between 2000 and 2013, nor was there for 'new hires' between 2001 and 2013. Given that 2013 was an outlier year for new hires, a test of significance was also carried out dropping the 2013 point. If anything, there was an indication of a slight increasing trend (higher school education new hire salaries compared with other professional new hire salaries).[98] A pattern of a decreasing ratio can certainly be ruled out. The trend of declining maths performance over the last 10 years is not likely explained by declining relative teacher salaries.

98 The T stat was 2.13, which was significant at the 10% level but not at the 5% level.

Figure 9. Maths performance and median teacher salaries relative to other professions (2000 to 2013)



Sources: Linked Employer-Employee Data, "Table 4: LEED Measures, By Industry" (based on ANZSIC06) (Wellington: Statistics New Zealand, Data Extracted 9 April 2015); Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 5 Students' Mathematics Achievement in 2010/11," New Zealand Results from the Trends in International Mathematics and Science Study (TIMSS) (Wellington: Ministry of Education, July 2013), p. 27; Robyn Caygill, Sarah Kirkham and Nicola Marshall, "Year 9 Students' Mathematics Achievement in 2010/11," New Zealand Results from the Trends in International Mathematics and Science Study (TIMSS) (Wellington: Ministry of Education, July 2013), p. 29; Steve May, Saila Cowles and Michelle Lamy, "PISA 2012 New Zealand Summary Report" (Wellington: Ministry of Education, December 2013), p. 13.

SUMMING IT UP

Over the last 10 years, student maths achievement in New Zealand as measured by TIMSS has generally trended down, while teacher salaries relative to other professionals' salaries have not. Primary school teachers, on the whole, may not have the required levels of maths proficiency for teaching maths themselves. But the relative salary data indicates that poor maths competency among primary school teachers is unlikely to have changed much over the last 15 years.

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CHAPTER FOUR
CENTRAL PLANS

Before considering solutions for improving maths education, it is necessary to draw attention to the wider context of the structure of New Zealand's education system, and review some of the lessons that can be learned from the mistaken assumptions behind the Numeracy Project. After all, the Numeracy Project was a centrally planned solution for improving maths education in a decentralised and self-managing education system. Singapore and New Zealand illustrate the differences between centralised and decentralised decision making.

SINGAPORE VS NEW ZEALAND

As discussed in *Around the World,* The New Zealand Initiative's report on teacher quality in top education systems, Singapore is a city state geographically smaller than Auckland, broken up into four school districts.[99] The combination of geography and a political climate of authoritarian democracy enables easy central planning in Singapore. As one policymaker in Singapore explained to this researcher, if the Minister of Education there wanted to see all the school principals in a room together the next day, it would happen. Changing something from the top down is far more appropriate and, importantly, possible in a system like Singapore's.

New Zealand's education system, by contrast, is decentralised to local school boards made up of parent representatives for each of the 2,500 schools under the Tomorrow's Schools policy introduced in 1989. This makes more sense in a geographically dispersed population. Each school receives an operational fund, and has the freedom to tailor the curriculum and arrange schooling to meet the needs of the local community. The National Curriculum is a loose framework for schools to adapt to their local contexts. The thinking behind self-managing schools was to move away from a centrally planned one-size-fits-all system and towards a diverse schooling system that catered to children from diverse backgrounds with diverse learning needs and goals.

A BLANKET APPROACH

The Numeracy Project, however, put in place a centralised approach to teaching maths on a self-managing school system. Although the Numeracy Project was never mandated, the Professional Development (PD) that came with the Numeracy Project was provided for free by the Ministry (that is, schools did not have to pay for it from their operational funds) and included release time for teachers. It is not surprising then that the vast majority of schools took up the Numeracy Project.

Wright acknowledges that during 2001–05, when the Numeracy Project was scaled up to a nationwide level, it lost the flexibility that its forerunner programmes had.

> The freedom and flexibility of the smaller projects was lost in the interest of national coordination. You put some tools in place and they become a hegemony – a practice – and that restricts your ability to say, can we do this any better?
> — Vince Wright, ex-Ministry of Education, personal interview (16 December 2014)

Indeed, Wright and others have emphasised that abandoning the written methods was never the intention of the Numeracy Project. The plan was to achieve the right balance in maths education. In

99 John Morris and Rose Patterson, *Around the World: The Evolution of Teaching as a Profession*, op. cit.

practice, though, that has not been achieved. It is possible that attitudes were already shifting, and rolling out a national programme put momentum behind those attitudes. Regardless of whether the NDP changed attitudes or reflected changing attitudes, it has changed the way maths is taught. Centrally planned systems tend to cause large pendulum swings and ignore local nuances.

COSTS AND BENEFITS

It is difficult for policymakers and education researchers to put together a cost-benefit analysis of centrally planned programmes like the Numeracy Project. Although schools did not have to pay the PD costs (including backfilling) when the Numeracy Project was rolled out, that funding has since been dropped so schools now face the direct costs of the new methods of teaching maths.

It may be that learning multiple mental strategies for approaching maths problems alongside traditional methods and a proficiency in the basics is the best approach. However, schools face resource constraints, such as teacher time, and competing priorities – and must make trade-offs with their resources. The new methods of teaching maths are probably far more resource heavy. They are also likely to be more demanding on children, who only have a limited amount of daily energy for learning new material, and choices for where to direct children's attention have their trade-offs too. Only schools can know their own resource constraints, pressures and priorities.

Finally, taxpayers pay for the Numeracy Project, not only from the $70 million allocated centrally for its rollout, but for the continuing costs to schools. For that, it is reasonable to expect improvements in maths performance. Stagnating, if not declining, performance suggests the Numeracy Project as it has played out in schools has returned little benefit at much cost.

ACCOUNTABILITY

Cost-benefit considerations about any school programme prompt questions of accountability. It is unfair to hold teachers and schools accountable. Although the Numeracy Project was never mandated, the funding that came with it made it hard for schools to say no. The new methods have now made their way into the National Curriculum and the National Standards, which schools use to guide their curriculum development.

Parents have the most interest in seeing their children succeed in life. The power must be put back in the hands of parents to hold schools accountable for ensuring their children learn. If parents see their children struggling with maths, their concerns should be a catalyst for change. Theoretically, in a self-managing system, ideas that do not work should not stay around long. However, the system lacks some components of self-management that would allow this. The New Zealand Initiative's next education research stream will examine these issues in depth.

DIVERSITY STILL EXISTS

On the one hand, rolling out a national programme for improving maths performance has resulted in a kind of hegemony in the way maths is taught. On the other hand, the beauty of New Zealand's system is that schools can resist top-down approaches, or interpret them in their own way. There is likely to be a lot of diversity in how the Numeracy Project is interpreted at the local level. Many schools will have the right balance in their curriculum with more emphasis on learning facts and processes. However, many schools may be wary of changing things too much when they do not align well with the National Standards, which embed within them some of the Numeracy Project methods.

THE REAR VIEW MIRROR

Nationally aggregated statistics indicate past maths performance and schools across the country are likely adjusting their school-level policies, curriculums and resources for maths teaching in response to their individual school maths performance.

Central policies are therefore not appropriate for changing a major aspect of the education system, such as the way maths is taught. The main lesson from the Numeracy Project is that well-intentioned ideas are often misinterpreted and misapplied. New Zealand's system is not easy to control from the top down, nor should it be. The New Zealand Initiative's solutions for improving maths performance speak directly to schools rather than the Ministry of Education, which by its nature as a bureaucracy – is a battleship slow to change. Schools, by contrast, are kayaks that can quickly change direction. But accountabilities must be in place. The New Zealand Initiative will be exploring this further in its next series of education reports.

SUMMING IT UP

The Numeracy Project was a centrally planned approach to changing the way maths is taught in New Zealand primary schools. It cost $70 million centrally, and schools also face the costs of the extra resources the new methods likely require. Yet maths performance has been in decline. The Numeracy Project illustrates that rolling out a centrally managed policy change in a self-managing school system does not work as intended. And, it raises questions about who is accountable for such programmes.

THE NEW ZEALAND INITIATIVE

CHAPTER FIVE
SOLUTIONS

The New Zealand Initiative typically follows a research model of a series of three reports. The first identifies a problem and how it arose, the second looks at policy solutions overseas that have addressed similar problems, and the third recommends policy solutions. This report is a standalone one. It proposes ideas to be debated and discussed among parents, the public, educators and policymakers. Furthermore, the recommended solutions are ones that can be adapted to local contexts.

To review the problems identified in this report, progress in maths education in New Zealand is being held back for three reasons. First, the pendulum swing that accompanied the Numeracy Project towards 'relational' learning and away from 'instrumental' learning means that in many primary schools, children are not learning the basics of maths.

Second, the education system as it stands is not attracting enough people with the levels of maths competency necessary for teaching the subject, particularly with the newer methods.

Third, teachers are not adequately trained in Initial Teacher Education (ITE) in maths knowledge and maths teaching, and there are no objective standards of teacher maths competency.

This report makes six main recommendations. Not all are at ideas at the central level, recognising that multiple stakeholders at different levels of the system have the power to improve maths instruction.

RECOMMENDATION #1: PARENT PRESSURE

Key change makers: Parents

If anything can be learned from the mistakes of the Numeracy Project, it is that parents should be heard when they raise concerns. Parents reading this report, particularly those who have noticed a lack of emphasis on maths basics, should mobilise to ensure schools are teaching children basic facts and procedural proficiency.

RECOMMENDATION #2: SHIFT THE BALANCE

Key change makers: Principals

As Ben Riley's research found, schools and teachers themselves have been asking questions about the Numeracy Project. It is likely that some schools rejected the Numeracy Project at the outset. Some would have interpreted the Numeracy Project as intended – a balance of older and newer methods. Others are likely responding to the poor outcomes and changing their maths curriculums now. In other words, different schools are at different stages. School leaders reading this report should reflect whether they have the balance between instrumental and relational learning, and adjust to suit. As below, rather than redesigning the curriculum from scratch, schools should copy curriculums of schools that have seen good results.

RECOMMENDATION #3: OFF-THE-SHELF CURRICULUMS

Key change makers: Principals, Teachers, Ministry of Education

The Ministry of Education should identify a handful of primary schools performing highly in maths at each decile level, and of those, identify schools that have "off the shelf" curriculums that can easily be shared with other schools. These schools should be asked to share these curriculums on 'Pond', a portal for educators to upload and share educational content, which was created by the Network for Learning (a Crown-owned Company set up by the government to create a managed internet network for schools) in 2014.

Schools would benefit from economies of scale with curriculum and lesson plans, which may be too time consuming for small schools to design on their own from scratch. This recommendation avoids the problem of a centrally prescribed curriculum, and gives schools the option to use a curriculum that has worked in schools serving similar student profiles. It is important to note that similar results cannot be guaranteed if difficulties with maths teaching are due to reasons other than the curriculum. This may need to be implemented by schools in tandem with improving teacher maths capabilities.

RECOMMENDATION #4: KHAN ACADEMY FOR TEACHERS

Key change makers: Principals, Teachers

School leaders (or other champions within schools) should investigate Khan Academy (https://www.khanacademy.org/), a free online resource for learning a range of subjects including maths at all levels from pre-school right through to secondary level. While this can be used with students, principals should look into using it as a resource for teacher professional development (PD) and encourage teachers to work through the maths courses. The courses use adaptive technology to tailor to individual skill levels. A champion within the school (perhaps the principal or another teacher who is determined to support teachers to improve their maths capability) can set up as the 'coach' and teachers as 'students' who work through the material at their own pace. The coach can monitor how teachers are doing to determine where school PD resources should be targeted to support teachers to improve.

RECOMMENDATION #5: MATHS TEACHING EXPERTS

Key change makers: Communities of Schools

The Investing in Educational Success (IES) policy[100] provides a great opportunity for schools and teachers to learn from one another to improve maths education. Under this policy starting in 2015, schools are banding together as Communities of Schools. Each Community is building a career pathway for teachers, where senior teachers share their knowledge and practice with other teachers across the Community. Communities could identify teachers with high levels of maths teaching proficiency when considering which teachers take on the new roles, as a mechanism for sharing maths teaching knowledge and practice. The IES policy, which brings together primary and secondary schools, also has the potential to open dialogue between the two and address the complaints of secondary schools that primary schools are not equipping students with the necessary foundations in maths.

100 Rose Patterson, *No School is an Island* (Wellington: The New Zealand Initiative, 2014).

RECOMMENDATION # 6: TEACHER MATHS PROFICIENCY CERTIFICATION

Key change makers: Educanz

A certificate of teacher maths competency should be designed to help bridge the gaps in the maths knowledge among the 27,000 primary school teachers in New Zealand. It would be optional rather than mandatory. If indeed teacher maths competency is valued by parents and schools, teachers at any stage of their career could aim to attain their certification. This would also indicate to principals the maths competency of teaching position applicants, and give teachers a competitive advantage when applying for teaching positions. School principals could inform prospective parents about the level of maths competency among their staff.

If this certification becomes valued, ITE providers too would feel the competitive pressure from prospective students to offer courses that lift maths competency to the level needed to gain their certificate of maths teaching proficiency, and could advertise as a competitive edge the proportion of their graduates who are certified. Teachers may undertake self-study or select PD programmes that improve their maths competency to attain the certification. Such a system would allow quick identification of those who already have the requisite maths competency. Finally, gaining certification may appeal to the intrinsic motivation teachers have. The vast majority of teachers in New Zealand are in their job because they care about children and their educational outcomes. Many will feel a lack of confidence in their own maths and feel a desire to improve.

The Educational Council of Aotearoa New Zealand (Educanz), the new professional body set to replace the New Zealand Teachers Council (NZTC), should commission the test and award certification. As discussed in Chapter 3, the NZTC's current Graduating Teacher Standards are vague and subjective. Educanz could make expectations of appropriate levels of teacher maths competency much more explicit by providing this test and certificate for teachers.

CONCLUSIONS

New Zealand primary school students are struggling with maths. Despite millions spent on introducing new methods of maths teaching to primary schools 15 years ago, maths results have been in decline. The Numeracy Project's legacy continues and the new methods are now the norm. Yet there was no accountability for the Numeracy Project, the costs outweighed the benefits, and children are missing out on gaining fluency in basic maths procedures and knowledge. It is this lack of emphasis on the basics that holds children back from thinking mathematically, and this closes doors too early in life.

So what are the answers? It is not appropriate to go back to learning algorithms without understanding, but nor is it appropriate to discard traditional methods completely. Instead, schools should aim to strike a balance, putting some more emphasis on fluency with written methods and basic facts, and enabling children's instrumental and relational understanding to build on each other.

Schools should alter the balance depending on where they are at now with their maths instruction. They are much more nimble, as individual entities, than the Ministry of Education, and should therefore lead the charge. And parents should be the drivers of that charge. New Zealand's school system is not supposed to be top down, but bottom up. If parents are concerned about maths instruction, they must mobilise and make those concerns heard.

Primary school teachers are also in a position to improve educational opportunities for their students by improving their own maths abilities. Many are simply not proficient enough in maths themselves to teach the subject. This is not to point the finger at teachers. Many would not have had good opportunities themselves to learn maths at school. But teachers are motivated to see students do well. An optional certificate of maths teaching proficiency would provide an objective standard of the level of maths required for teaching maths in primary schools. It would not only measure teachers' maths knowledge, but critically, their knowledge of how to represent maths in a way that children can understand. This certification would provide a much needed objective signal of maths teaching proficiency, to initial teacher education (ITE) and professional development (PD) providers, to principals, and to parents. If there is enough desire for change, and if the certification does indeed become a good signal of actual maths teaching capability, the system will align towards it.

Finally, the Ministry of Education should identify schools achieving in maths and encourage those schools to share their curriculums through the Network for Learning's 'Pond' portal, giving thought to addressing the time barriers involved for schools. This approach avoids moving to a top-down prescriptive curriculum. Instead, it recognises that there is excellence in New Zealand's system and enables curriculums that work in practice to be shared with other similar schools.

New Zealanders have been lamenting the state of maths education now for more than 30 years, but maths skills are increasingly in demand in the modern age. If we are to prepare children for a range of choices, maths must be part of that preparation. At every level of the system, people should consider how to apply the recommendations of this report in their context, and take action. These actions might seem small, but they will add up, not just to better maths results for the sake of better maths results, but to better opportunities for the next generation.

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THE NEW ZEALAND INITIATIVE

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Unaccountable: Why millions on maths returned little is about a big policy failure.

More than 15 years ago, New Zealand introduced the Numeracy Project. This programme for primary school teachers changed the way maths is taught. But it has cost too much and is holding children back from learning.

Children now learn multiple methods for solving maths problems, but they are not learning basic facts and written methods.

And too many teachers do not have good maths themselves. But teachers can and must improve. Children need a good grasp of maths in primary school. Otherwise, we limit their options for secondary school and beyond.

This report shows how parents, schools, teachers, and the government can improve outcomes. New Zealand has been lamenting maths education for more than 30 years. It is time to get the maths equation right.

"IPENZ welcomes the Initiative's report on maths teaching. We are concerned to see that the maths achievements of New Zealand students have flat-lined or declined, and support a review of the way maths is taught in schools. Good maths skills are a fundamental prerequisite for engineering and technology-based careers, and for building New Zealand's economic and social wellbeing."

The Institution of Professional Engineers New Zealand (IPENZ)

"With this report, the New Zealand Initiative is raising a timely discussion on this important subject. A more complex, interconnected and data-driven world makes basic numeracy even more important, because there are more demands on us for rapid calculation and decision-making. A solid grasp of maths is necessary if our children are to grow up with the confidence and skills they need to take full advantage of the opportunities that come their way."

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